



Comparative Analysis of International Offshore Wind Energy Development

REWIND OFFSHORE

March 2017

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The Carbon Trust has been at the forefront of the offshore wind industry globally for the past decade, working closely with governments, developers, suppliers, and innovators to reduce the cost of offshore wind energy through informing policy, supporting business decision-making, and commercialising innovative technology.

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EXECUTIVE SUMMARY

THE OFFSHORE WIND SUCCESS STORY

Offshore wind power is on the cusp of exponential growth, with installed capacity set to nearly triple in the period from 2015 to 2020¹. This growth is being accompanied by marked cost reduction, with recent auction tenders suggesting that costs have fallen by 60% compared to 2010 levels, already surpassing industry cost targets for 2025, eight years ahead of schedule. The cost reduction is a signal of the industry's growing maturity, with high levels of competition across a robust industry structure.

Furthermore, having been pioneered in a small handful of European countries, offshore wind is set to expand geographically, with considerable market growth forecast both within and outside Europe, particularly in East Asia and North America. There are important lessons that can be learned and transferred between maturing and emerging markets. This report, commissioned by the IEA-RETD, presents a comparative analysis of approaches to offshore wind development internationally. It has identified a series of key lessons learned across three primary focus areas: government policy & regulation (Section 3); the development of industry structures (Section 4); and the risk management strategies adopted by offshore wind developers (Section 5).

A MATURING OFFSHORE WIND SECTOR

A thriving offshore wind sector requires involvement from a broad range and type of organisations, from developers to various suppliers, contractors, financiers, and regulators. The strength of this industry structure is vital to the successful delivery of offshore wind projects and achieving long-term cost reduction. Supportive policy frameworks in Europe have enabled the development of a robust industry structure which has evolved over the past decade. Following initial periods of market innovation, adaptation, and stabilisation, the European offshore wind sector is set to enter a period of maturation, with increasing competition from a large number of established industry players. Indications of market maturation include:

- Steep cost reduction evident in several European countries.
- Several European markets have become commoditised, with financial investors, commonwealth funds and pension funds now investing in operating assets, allowing utilities to recycle capital to new projects.
- Perceived risks from the investor and finance community have been reduced due to growing confidence in the ability of developers and the supply chain.
- Project margins have reduced over the last five years due to increased confidence in the industry and perceived reduction of residual risk levels.
- Consolidation of industry developers, particularly in the UK where significant exits have left fewer players in the market.

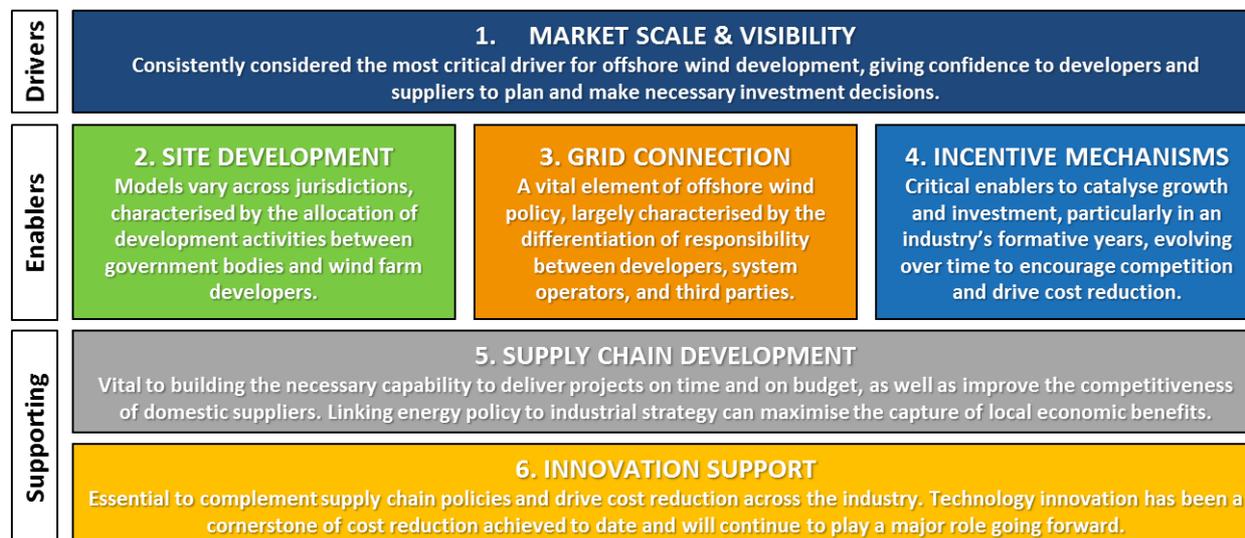
However, while the European market may be demonstrating signs of maturity, emerging markets outside Europe are at a much earlier stage, with far more nascent industry structures. Furthermore, while the European market has benefitted from clustering around the North Sea region, which has a rich background in offshore engineering and maritime sector activities, more isolated emerging markets are expected to encounter greater challenges. Lower cumulative market size and a lack of established suppliers are therefore likely to require greater government intervention to reduce investor risk and kick-start the offshore wind industry. Nevertheless, the expansion of several key European players to East Asia and North America is a sign of increased confidence in these markets.

¹ Installed capacity of 12.2 GW in 2015 (GWEC, 2016) is set to increase to 36.2 GW by 2020 (Carbon Trust analysis of project pipelines, central scenario).

SIX PILLARS OF EFFECTIVE OFFSHORE WIND POLICY

The cost reduction achieved in recent years can to a large extent be attributed to supportive policy frameworks in several European countries, which have catalysed growth and nurtured the development of a robust industry structure. Successful regulatory frameworks adopt holistic support policies across six key pillars (Figure 1).

Figure 1. Six pillars of effective offshore wind policy



Policies within these pillars have evolved over time, with greater government intervention in the industry's formative years to de-risk private sector investment, before transitioning to more market-based mechanisms as the sector has matured. Policies have also evolved to transfer best practice between regimes and in response to local conditions. This evolution is highlighted by two emergent policy trends:

- 1. Competitive auctions:** With offshore wind maturing as an energy technology and with increasing pressure to drive down costs, incentive mechanisms have evolved from grants and fixed remuneration support to competitive auctions in several countries (e.g. Denmark, Germany, Netherlands, UK). Recent auction tenders suggest that this approach has been effective in delivering steep cost reduction, but capacity constrained auctions have also increased price and allocation risk for developers.
- 2. Centralised development models:** To balance increasing price and allocation risk for developers from capacity constrained auctions, as well as to manage onshore grid constraints, several governments are taking on greater up-front risk in the development stage. Development de-risking activities, such as obtaining consent, undertaking site investigations, and securing grid permits, can limit the risk exposure for prospective developers who would otherwise need to invest considerable sums undertaking such activities themselves without any guarantee of ultimately succeeding. As a consequence, there has been a shift from typical open door approaches to centralised site-specific tendering, often with the provision of offshore transmission assets (e.g. Denmark, the Netherlands, and Germany).

CHANGING RISK PROFILES FOR DEVELOPERS

Whilst the overall risk levels for offshore wind are decreasing, the policy trends noted above are impacting on the perceived risk profile for developers. Namely, the transition to competitive auctions has led to an increase in allocation and price risk, particularly in markets with decentralised development models, such as the UK, where developers must take on the risk and cost of site development. The move to centralised development models is an effort to combat this, but allocation risk remains high and also introduces reduced opportunities to develop a portfolio of projects. Greater government control can also create risks of inefficiency for some developers who prefer to have greater control of site development and grid asset construction and operation. Nevertheless, government site de-risking activities are generally considered both desirable and necessary in competitive auction systems.

While certain risks are increasing, the growing maturity of the industry is seeing a reduction in other areas. The transition to centralised auctions is reducing development risks, while greater track record and experience with increasing cumulative capacity, together with a strengthened industry structure, is reducing technical risks, both in construction and operational phases. This, in turn, is resulting in greater trust within the investment community, attracting a more diverse range of funders, including conventionally risk averse investment banks and pension funds. However, more challenging site conditions, larger equipment requirements and larger projects, combined with increasing cost pressures, present future challenges. Supportive government policies and strengthened industry collaboration will therefore be needed to mitigate these risks and continue delivering cost reduction across established and emerging markets.

RECOMMENDATIONS FOR POLICY MAKERS

Analysis of the evolution of offshore wind policies has revealed several important lessons with regard to best practice approaches for stimulating deployment and reducing costs.

Governments should re-evaluate their offshore wind ambitions in light of accelerated cost reduction:

Offshore wind is entering a maturation phase which has already seen costs fall dramatically in early tender rounds. With further cost reduction anticipated, offshore wind could potentially be fully integrated into the market on a competitive basis in some European countries within the next decade². In light of this development, governments should re-evaluate their energy strategies to consider raising ambitions for future deployment.

Governments should consider implementing near-term roadmaps to hedge against long-term uncertainty: Long-term visibility is a common request from industry players, but does not always align with short term political cycles. As a compromise, near-term roadmaps – tied to suitable support mechanisms – can provide the necessary certainty and stability to increase market confidence. This approach has been particularly effective in the Netherlands, with Germany set to adopt a similar approach.

Competitive auctions can drive down costs, but should be accompanied by government de-risking activities: The transition to competitive auctions has been hugely effective in delivering steep cost reduction. However, in order to achieve future cost reduction governments are likely to need to mitigate increased allocation and price risk by undertaking site development activities to de-risk investments from developers. Undertaking spatial planning and constraint mapping to identify sites, making site survey data publically available, and securing necessary permits can all significantly limit the risk exposure for developers. In countries with established industries, enabling the extension of existing sites can also unlock lower risk and lower cost means of adding new capacity.

Policymakers in more isolated emerging markets are still likely to require attractive support mechanisms and enabling policies to kick-start domestic industries: The progress and cost reduction achieved in Europe has been partly attributed to clustering and concentrated development around the North Sea region. For more isolated emerging markets, such as Japan, Taiwan, and the United States, greater public intervention is expected to be required to de-risk investment and develop the necessary industry structures to deliver cost-effective offshore wind projects.

² The Dutch Government expects to hold the first tenders for un-subsidised offshore wind farms by 2026, depending on electricity prices.

Governments must continue supporting technology innovation to achieve long-term cost reduction:

The cost reduction achieved in recent years has been largely driven by technology innovation. Despite the considerable progress made to date, policymakers should not step back from efforts to support research and development activities. Rather, government R&D support should be expanded to develop and de-risk technologies that will be crucial to achieving long-term cost reduction. This is particularly relevant in relation to developing larger turbines and associated supporting infrastructure, commercialising floating wind technology to unlock new markets for offshore wind, and developing technologies to withstand extreme weather conditions in these new markets.

Regulatory frameworks should encourage industry collaboration and information sharing: Despite the transition to more competitive market conditions, continued industry collaboration will be vital to accelerating learning and maximising the impact of both public and private investment. Governments should look to foster collaborative partnerships, forums, and programmes to overcome common challenges, particularly as the industry expands to new markets.

RECOMMENDATIONS FOR INDUSTRY PLAYERS

The offshore wind industry has evolved considerably in recent years: the supply chain has developed, developers have become better at managing risk, and the investment community has greater confidence in the industry as a whole. The following recommendations are derived from the lessons learned and should be applied by industry players in established and emerging markets.

Embrace collaboration within the industry to manage developer risks on large-scale projects under auction regimes: The introduction of auction regimes in Europe has introduced greater allocation risk for developers. Furthermore, project capacities are growing and with it the capital required and impact of failure of a single project on a developer's overall business. Developers have approached these trends through collaboration and forming of consortia between developers and/or with stakeholders from the supply chain to share risks and increase the chance of winning bids, as well as maintain a reasonably-sized project pipeline.

Build a strong management team and have fall-back plans in place: Developers' risks are now well understood and effective risk mitigation strategies have been identified. To ensure industry lessons learned are applied and learning is continued, an experienced project management team is pivotal to the success of a project, as well as robust planning and fall-back plans. Developers should involve independent advisors early in the planning phase when optimisation of the procurement and execution strategy is feasible and has the potential for large savings later on in the project.

Build strong relationships with regulators, executing authorities, and third parties: In particular, in emerging markets, where the regulator has little or no experience with offshore wind, industry should engage early with regulators, interfacing authorities and third parties to clarify requirements and establish a collaborative and constructive dialogue. Industry players should participate in stakeholder consultations held by regulators to mitigate unrealistic requirements or unintended risks being introduced to developers and their funders.

Continue to innovate: European offshore wind tenders awarded in 2016 confirm that developers need to achieve material cost reductions to what has been seen in the industry to date. Developers cannot solely rely on established technologies, but need to seek to continue to innovate. This can be achieved through participation in industry R&D initiatives, collaboration with universities and supply chain or regulator-supported pilot-schemes. Developers should engage early with potential funders to familiarise them with potential innovations and risks mitigation strategies.

Engage more with the public to improve the public perception of the offshore wind industry: The public perceives offshore wind to be less reliable and more expensive than other forms of electricity generation. More could be done by the industry to improve its public standing by promoting the importance of offshore wind in maintaining grid stability, the recent gains in cost reductions, and the benefits to local and regional economies.

1 INTRODUCTION

1.1 OFFSHORE WIND: INDUSTRY OVERVIEW

Offshore wind has experienced considerable growth over the past 15 years, with global installed capacity increasing from just 83 MW in 2000 to 14.4 GW in 2016³. The vast majority of deployment to date (~87%) has been concentrated in the European region, where a healthy project pipeline means that growth is expected to continue over the coming decades, with larger projects using more advanced technologies in an increasingly mature industry, delivering electricity at lower cost and with greater efficiency. The success of the European offshore wind industry has inspired increased interest in new geographies, particularly in East Asia and North America, where there are ambitions to significantly ramp up deployment over the coming years. However, these nascent markets will face multiple challenges in kick-starting their offshore wind industries, with pressure to achieve low cost of energy, demonstrate benefits to local companies, and overcome unique technical challenges.

Despite some price volatility in the industry's formative years, the last 5 years have seen considerable cost reduction in Europe⁴, achieved through a combination of technological advances, supply chain maturity and economies of scale, together with the development of more effective developer and contracting models and more favourable financing terms from an increasingly diverse range of lenders and investors. The introduction of competitive auctions in several European markets has been particularly effective in driving down costs further to meet ambitious cost targets for the industry⁵.

The growth and cost reduction achieved in Europe has been underpinned by policy and regulatory frameworks which have incentivised steady deployment and attracted investment to the sector. This policy landscape has been marked by different approaches in different countries, with contrasting drivers and market conditions resulting in a mosaic of policy levers being applied. With various inter-dependent factors at play, there are inevitably trade-offs which policy makers must contend with, particularly in relation to how risk is distributed between government, consumers, and industry players. While some regimes have successfully struck an optimal balance to catalyse growth, some European markets have also experienced stalled growth from the introduction of ineffective policies and the uncertainty created from changes to government policy.

There are considerable lessons that can therefore be learned from European experience which can be transferred to emerging markets, and vice-versa as these new markets develop. Adoption of best practice policy and regulation can act as a catalyst to facilitate accelerated growth for these nascent industries, helping countries to avoid some of the pitfalls that have affected early-mover markets and maximise the efficacy of public spend in achieving strategic goals.

³ Global Wind Energy Council. 2017. *Global Wind Statistics 2016*. Available at: http://www.gwec.net/wp-content/uploads/vip/GWEC_PRstats2016_EN_WEB.pdf

⁴ In the UK, LCOE fell by 32% (£142/MWh to £97/MWh; or equiv. €166/MWh to €144/MWh) from 2010-2016 (CRMF, 2017). Recent auction tenders in Denmark and the Netherlands have achieved strike prices of €50-55/MWh, although this does not include the cost of grid connection or site development.

⁵ Industry target, depending on project jurisdiction of £100/MWh (UK) or €100/MWh (mainland Europe) by 2020. Several industry players, including DONG Energy and Siemens, have supported these targets. In the UK, the government has set a capped strike price of £105/MWh (equiv. €123/MWh) in the next auction round (expected in 2017), which will fall steadily to £85/MWh (equiv. €100/MWh) by 2025.

1.2 REPORT OUTLINE

This report presents a comparative analysis of offshore wind development internationally. The report takes a particular focus on different approaches to government policy, the development of industry structures in different markets, and different developer models and contracting strategies adopted.

An evaluation of the evolution of policy frameworks in leading offshore wind markets is provided, extracting insights and learnings that are relevant to both mature and emerging markets. In particular, the study aims to assess policy efficacy through the lens of how risk is assigned to different actors, including government bodies, consumers, developers, grid operators, and suppliers. In this regard, the report assesses risk distribution through the project lifecycle, together with how policy frameworks can influence developer risk and the development of industry structures.

The report is structured as follows:

2. Offshore Wind State of the Industry: Section 2 provides an overview of the state of the industry, including the drivers for offshore wind development, historic and forward-looking deployment across different markets, technology trends, and cost reduction achieved and expected over the coming decade.

3. Policy & Regulation: Section 3 includes an analysis of the evolution of regulatory frameworks to understand the effectiveness, strengths and weaknesses of different systems for the development of offshore wind projects. This section focuses on policy and risk from the perspective of national governments and its impact on project developers, with country case studies analysed to extract lessons learned.

4. Industry Structures: Section 4 provides a brief analysis of underlying industry structures to understand minimum requirements and key success factors. This section focuses on the key players in the offshore wind market and the formation of industry structures in different markets. Case study markets and market models are highlighted.

5. Project Risk Management: Section 5 includes a focussed analysis of interface and risk management regarding project development and technical, financial and administrative issues to better comprehend key success factors. This section focuses on risk from the perspective of project developers and the different developer models seen in the industry.

6. Recommendations: Section 6 includes conclusions drawn from the key findings. A series of recommendations are proposed to both policy makers and industry players on how to most effectively support offshore wind development and accelerate market growth.

It should be acknowledged that the policy approach adopted by different countries will depend on national strategic goals and local context, and as such the most effective policy measures will vary by market. However, the report aims to draw conclusions and recommendations on how policy makers can use different levers to achieve national aims.

1.3 APPROACH

The report has been produced as part of a collaborative partnership between the Carbon Trust, Mott MacDonald, and Green Giraffe, all of whom have leaned on considerable industry expertise from having been at the forefront of the offshore wind industry over the past decade. Insights have been drawn from a combination of in-house knowledge and experience, an extensive literature review, and a series of targeted interviews with key industry stakeholders. A detailed methodology is included in the Appendix.

2 OFFSHORE WIND: STATE OF THE INDUSTRY

2.1 WHY OFFSHORE WIND?

Offshore wind is widely considered a key energy technology in a growing number of coastal nations, helping governments to achieve a number of strategically important national goals; including:

Decarbonisation: Offshore wind is a highly scalable renewable energy technology, capable of generating large volumes of low carbon electricity. Unlike many onshore-based renewables, offshore wind is less constrained by land availability, enabling large scale build out to replace existing fossil-based power generation. Offshore wind farms can also be built quicker than most conventional power sources and at large scale, helping to accelerate the move to a decarbonised energy system. Offshore wind farms typically generate low carbon power for up to 25 years, with potential for repowering to extend generation asset lifetime.

Energy security: Large scale electricity generation from offshore wind reduces reliance on overseas energy imports, including volatile commodities such as gas and oil. An increasingly large share of domestic energy generation also presents opportunities for a country to become a net exporter of electricity. Offshore wind farms are particularly well placed to operate as transmission interconnectors, delivering low carbon electricity at closer proximity to demand centres.

Electricity system benefits: The ability to harness strong and abundant wind resource in offshore locations means that offshore wind can deliver consistent and predictable power to the grid. Offshore wind farms are able to operate with average load factors in excess of 40%⁶, considerably higher than most other renewable electricity sources. This results in a more consistent supply of electricity which is not constrained to cyclical load periods (i.e. day/night, tidal). Indeed, offshore wind is generally well aligned with energy consumption, with higher load factors during winter months when energy consumption is highest⁷. The difference between on- and off-shore weather patterns can also enable offshore wind to complement generation from onshore wind farms.

As electricity systems evolve and decarbonise, offshore wind could play an increasingly important role in load balancing. With an increasing share of electricity exported to the grid from a decentralised and variable energy sources, greater pressures will be placed on transmission networks. As a highly flexible and predictable source of generation with high load factors, offshore wind can both limit pressures on the onshore grid network and provide a tool for grid operators to better balance supply and demand. The predictability and flexibility of offshore wind means that it is well equipped to provide operating reserve and play a key role in stabilising the system. Opportunities for greater interconnection, for example across the North Sea, could also aid system balancing.

Costs to consumers: Following several years of technology proving, innovation, and de-risking, offshore wind is now considered a scalable, proven and maturing technology which offers considerable societal benefits to consumers. Recent cost reduction monitoring and contract awards suggest that the sector is delivering on its cost reduction potential, with further reductions expected over the coming decades (see Section 2.4).

Economic growth: With the right policies in place, the development of an offshore wind sector can bring considerable local economic benefits. Offshore wind creates new business opportunities in the supply chain, particularly those in synergistic sectors such as onshore wind, oil and gas, and marine engineering. As well as creating jobs to supply a domestic market, initiatives that stimulate innovation can also boost exports to overseas markets.

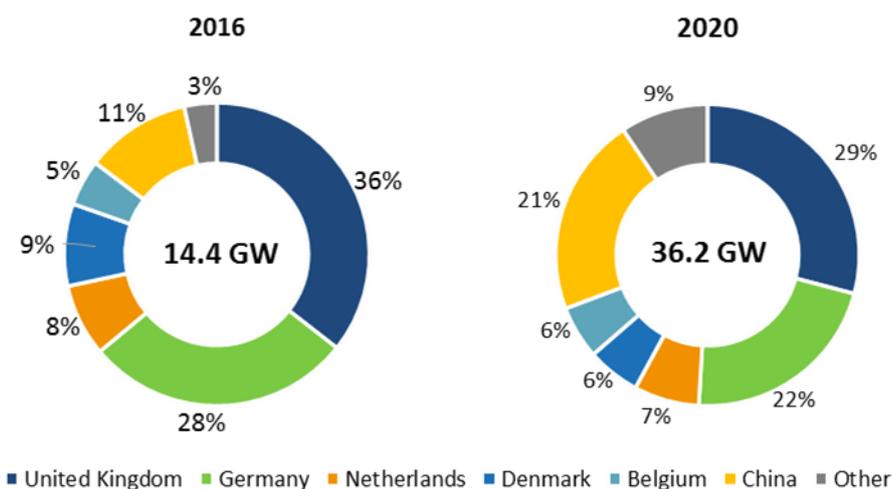
⁶ WindEurope. 2017. *Annual Offshore Statistics 2016*. Available at: <https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-Annual-Offshore-Statistics-2016.pdf>. Annual load factors in Europe typically range from 33-43%.

⁷ London Array achieved an average load factor of 78.9% in Dec 2015. WindPowerOffshore. 2016. *London Array breaks offshore production record*: <http://www.windpoweroffshore.com/article/1378756/london-array-breaks-offshore-production-record>

2.2 DEPLOYMENT TRENDS

Offshore wind deployment trends have been intimately tied to government policies to first demonstrate and develop the technology, before steadily ramping up build out across a number of front-runner markets. As of the end of 2016, total installed capacity now stands at 14.4 GW, the vast majority of which (~87%) is concentrated in Europe (Figure 3). This level of deployment may be considered modest relative to that seen in onshore wind (~472 GW cumulative installed capacity as of end 2016⁸), but the offshore wind sector is on the cusp of a period of exponential growth. Under a central deployment scenario, offshore wind installed capacity is expected to almost treble from 2015 levels to ~36 GW by 2020 (Figure 2), with annual installed capacity of ~4-6 GW over this period (Figure 3).

Figure 2. Offshore wind market share



Sources: WindEurope; 4coffshore; Carbon Trust analysis⁹

The majority of this growth is again expected to be seen in Europe, particularly the UK and Germany, however the emergence of the People's Republic of China (hereafter 'China') as an offshore wind superpower, in addition to modest additional capacity in several emerging markets, will see offshore wind become a mainstream energy technology internationally. Beyond 2020 the pipeline is less clear, but several governments at both national and regional levels have already outlined commitments and targets for offshore wind deployment, while others have indicated aspirations to increase investment in the sector.

In addition to the current 'big six' leading markets (Figure 2), new emerging markets are expected to increase their activity in the offshore wind sector, particularly in countries beyond the traditional European stronghold, such as Japan, Taiwan, South Korea, and the United States. Within Europe, outside the current market leaders, France are expected to significantly increase deployment from 2020, with several projects announced and commitments for further build out of both fixed and floating offshore wind. Growth elsewhere in Europe is expected to be modest under current policy regimes, but several project sites have been identified in new markets, particularly in the Baltic Sea (e.g. Finland, Poland). The emergence of floating wind technology could also unlock new sites for offshore wind in deeper waters in the Atlantic and Mediterranean.

⁸ Global Wind Energy Council. 2017. *Global Wind Statistics 2016*. Available at: http://www.gwec.net/wp-content/uploads/vip/GWEC_PRstats2016_EN_WEB.pdf

⁹ Pipeline data is based on a central scenario of deployment, according to probability of project build.

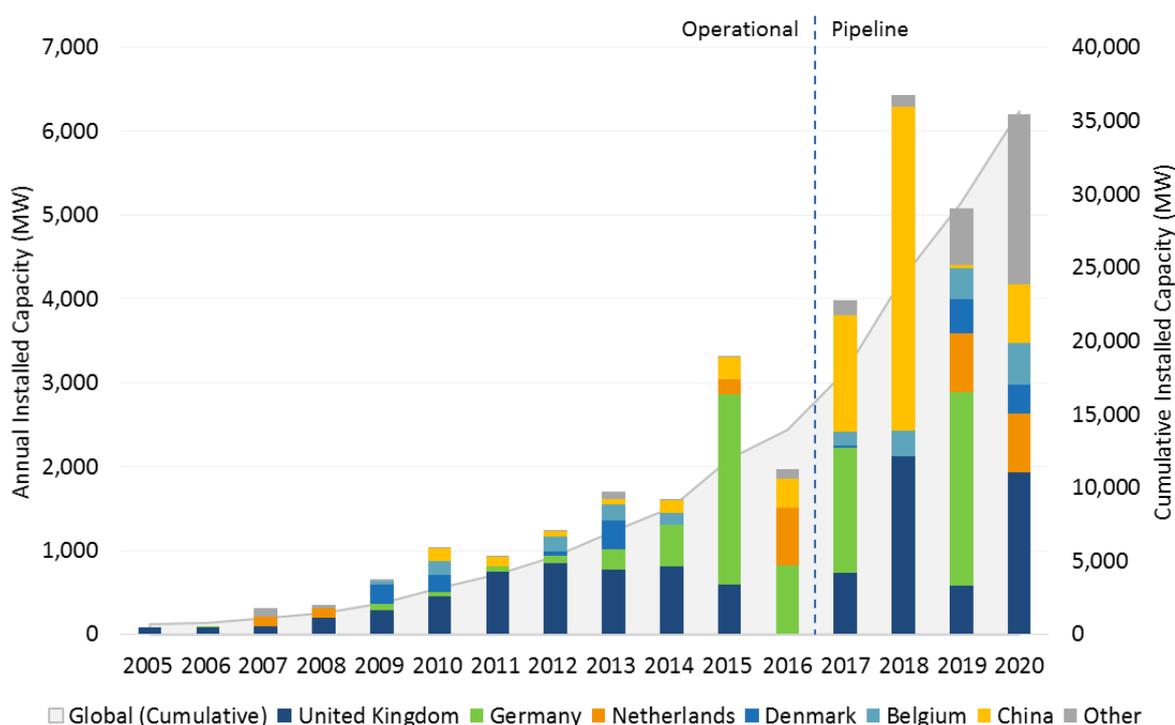
Influence of policy on deployment trends

A closer scrutiny of annual installed capacity (Figure 3) highlights the impact of government policy on offshore wind deployment. The UK’s position as the world’s leading market can be tied to a supportive regulatory environment from the early 2000s onwards which included: a capital grants scheme to incentivise early demonstration projects; introduction of a market-based remuneration systems (Renewables Obligation) with attractive support levels for offshore wind; and phased leasing rounds, administered by The Crown Estate, which sent a strong market signal for the UK’s long-term deployment goals. However, a lull in deployment in 2016 can be partly attributed to disruption and uncertainty caused by Electricity Market Reform in the UK, in which Renewable Obligation Certificates have been replaced by competitive and capacity-constrained Contracts for Difference.

In Germany, despite ambitious plans to become a leading market for offshore wind, deployment stagnated from insufficient support levels and a series of major delays to the construction of offshore transmission assets in the North Sea (see Section 3.3 on Grid policy). However, with these issues now alleviated, offshore wind installed capacity is increasing sharply as annual installed capacity averages >1 GW from 2015-2020¹⁰. From 2021 to 2030, annual installed capacity will be more predictable from the introduction of a centrally coordinated auction system, which will limit installed capacity to 500 MW per year from 2021-2022, 700 MW per year from 2023-2025, and 850 MW per year from 2026-2030.

A similar approach adopted in the Netherlands will see 700 MW of installed capacity per year for 5 years between 2019 and 2023. The success of the first two auction tender rounds has triggered calls for increased build out within this period and in the subsequent deployment plan to 2030.

Figure 3. Annual and cumulative offshore wind installed capacity



Sources: 4coffshore; WindEurope; Carbon Trust analysis¹¹

¹⁰ It should be noted that the phasing of deployment is expected to vary over financial years, as wind farms come online.

¹¹ Pipeline data is based on a central scenario of deployment, according to probability of project build.

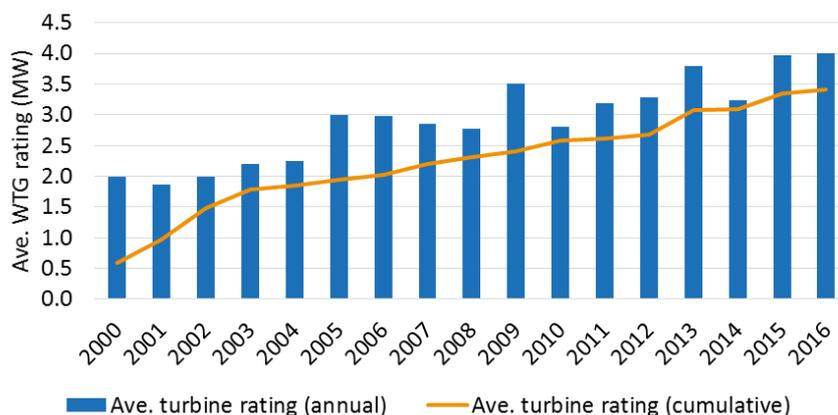
2.3 TECHNOLOGY TRENDS

Alongside steadily increasing deployment there have also been major trends in offshore wind technology. The most notable driver has been the increase in turbine size, with average turbine rating (cumulative) increasing from ~0.6 MW in 2000 to ~3.4 MW in 2016 (Figure 4). In 2016, average turbine rating (annual) reached 4 MW, however isolating European projects revealed a higher rating of 4.8 MW, driven by several projects using 6 MW turbines. In less mature markets outside Europe, such as China, turbine rating is typically lower, but expected to increase as the industries mature and develop the necessary infrastructure for the installation of larger turbines.

Turbine rating is expected to continue increasing up to and beyond 2020, with the introduction of 7-9 MW turbines in upcoming European projects¹². A quadrupling in turbine rating from 2 MW to 8 MW has been accompanied by a doubling in rotor diameter from 80 metres to 164 metres¹³ and the fewer assets and supporting infrastructure required for the same power output has been a major driver of cost reduction in the industry. Although yet to be announced, it is expected that 10+ MW turbines will soon be available on the market.

Similarly, average project capacity (cumulative) has increased considerably, reaching ~100 MW in 2010 and ~163 MW by 2016, with expectations to reach ~233 MW by 2020. However, these averages include several small scale demonstration and pilot projects. In mature European markets, individual commercial projects are far larger; for example, UK projects reaching FID in 2016 had an average project capacity of 586 MW, including the 1.2 GW Hornsea One project. This increased scale is another important driver of cost reduction across the industry.

Figure 4. Average turbine rating (annual and cumulative)



Sources: 4coffshore; WindEurope; Carbon Trust analysis¹⁴

Turbine innovation has acted as a catalyst for technology innovation in the supporting infrastructure for offshore wind farms. Foundations have had to adapt to supporting larger turbines, as well as move into deeper water and complex seabed conditions. In addition to the advent of novel foundation designs, such as suction buckets, gravity base structures, and twisted jackets structures, there has been considerable innovation in pushing the boundaries of conventional monopile and jacket foundations. For example, having originally been considered limited to ~20 metre water depth, research and development activities to optimise monopile designs means that these remain the most common foundation choice, capable of supporting large turbines in water depths up to ~35 metres.

¹² Siemens 7 MW and 8 MW; MHI-Vestas 8 MW and 9 MW.

¹³ Reference turbines: Vestas V-80 2 MW; MHI-Vestas V-164.

¹⁴ Running average – includes all turbines installed since 1990. Average project capacity limited to wind farm with 10+ turbines.

Higher power output from individual turbines and overall project capacity (Figure 4), combined increasing distance from shore, has led to considerable innovation in the electrical systems for offshore wind farms. Intra-array cabling is moving from 33kV to 66kV, which will enable larger turbines to be connected in ring circuits, reducing losses and increasing redundancy in the case of cable faults. Meanwhile, both HVDC transmission technology and optimised HVAC transmission technology are enabling wind farms to be located further from shore to access higher wind speeds without incurring major transmission losses.

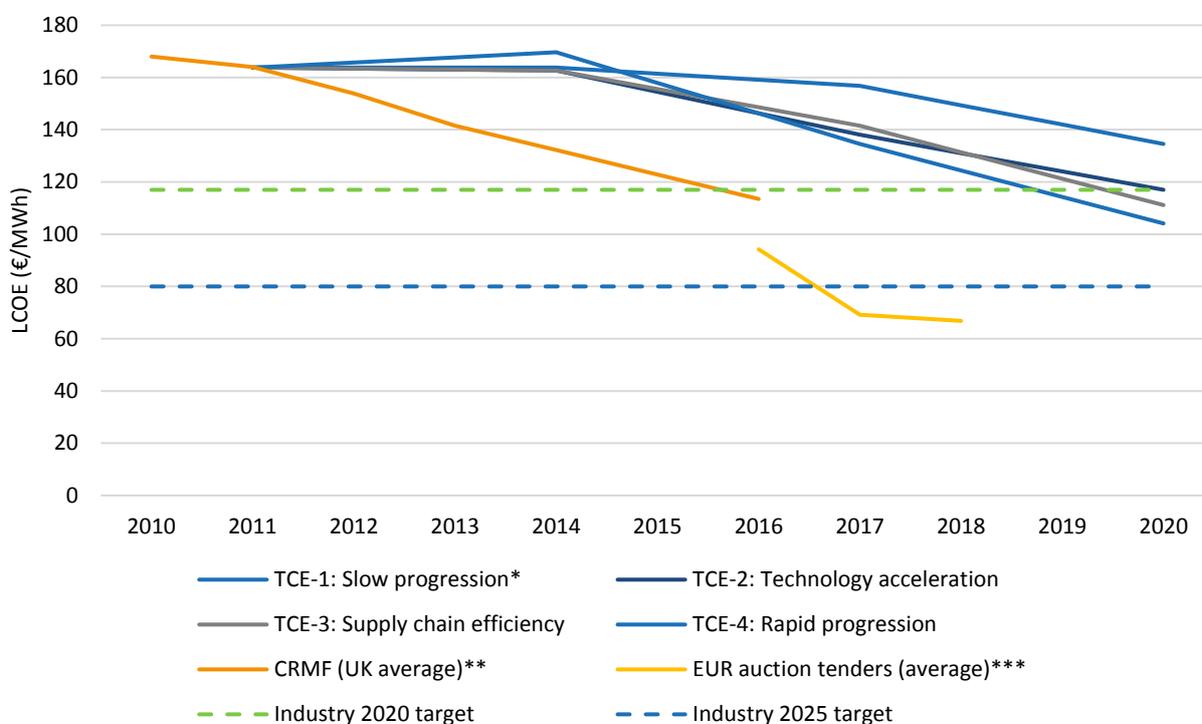
Further technology advancements have been seen in installation processes and bespoke installation vessels, access vessels and crew transfer systems, wind resource measurement, and modelling of wake effects and turbulence in wind farm arrays. Floating offshore wind is another rapidly emerging technology which could unlock vast areas with high wind speeds in deep water locations. As the sector continues to grow and mature, further innovation is expected and will be vital in continuing to reduce costs and expanding offshore wind energy to new markets.

2.4 COST TRENDS

Importantly, the deployment and technology trends observed have successfully delivered marked cost reduction. Despite some initial cost increases from 2005-2010, caused by a combination of fluctuating exchange rates, rising commodity prices, supply chain bottlenecks, and an under-appreciation of costs in early projects, these volatilities have largely stabilised. Since 2010, the industry has seen marked cost reduction, particularly with the introduction of competitive auctions.

Analysis for the UK's Offshore Wind Programme Board under the Cost Reduction Monitoring Framework has revealed that the levelised cost of energy (LCOE) for UK projects, which account for the majority of global deployment over this timescale, has decreased by ~32% from 2010 to 2016. The reduction from £142/MWh (equiv. €166/MWh) for projects reaching financial investment decision (FID) in 2010-2011 to £97/MWh (equiv. €114/MWh) for projects reaching FID in 2015-2016 means that the industry has surpassed its 2020 cost target (~€117/MWh¹⁵) 4 years ahead of schedule. The level of cost reduction has also exceeded even the most ambitious projections set at the beginning of the decade (Figure 5).

Figure 5. Offshore wind cost trends in Europe¹⁶



* The Crown Estate (TCE) Cost Reduction Pathways (2011); ** Cost Reduction Monitoring Framework (2017)

*** Includes grid connection and site development costs for NL and DK projects (uplift of €14/MWh). It should be noted that many of the 'actual' projects reaching FID have not yet been built.

¹⁵ Industry target of £100/MWh (equiv. €117/MWh) in the UK and €100/MWh in Europe (equiv. to €114/MWh with uplift for grid connection and site development; see footnote 17).

¹⁶ TCE 1-4 represent scenarios for offshore wind cost reduction from The Crown Estate Cost Reduction Pathways study in 2011. CRMF (Cost Reduction Monitoring Framework) represents anonymised actuals from UK projects reaching FID in 2010-11, 2012-14, and 2015-16, respectively. Auction tenders represent an average strike price from projects awarded contracts under competitive auction systems (see Table 1; uplift of €14/MWh to account for grid and site development costs; see footnote 17).

In recent years the pace of cost reduction has accelerated further, largely driven by the introduction of competitive auction-based tendering systems in several front-runner countries, including the UK, Denmark, and the Netherlands. Table 1 includes details of the projects awarded contracts under competitive tenders since 2016, with uplift of €14/MWh applied to European projects where grid connection and site development are external to the awarded strike price¹⁷. The cost drivers for each project vary, depending on the regulatory framework, site conditions, and project size, but a dramatic reduction in cost is evident across markets. Strike prices in the most recent contract awards, with FID expected in 2017 and 2018, suggest that the industry has already exceeded its 2025 cost target (€80/MWh, incl. grid connection¹⁸) 8 years ahead of schedule.

Table 1. Projects awarded subsidy contracts through competitive auction tenders in Europe.

	Year (FID)	Year (online)	Capacity	WTG rating	Water depth (ave.)	Distance from shore	Tariff (local currency /MWh)	Tariff (€/MWh)	Tariff (€/MWh - adjusted ¹⁹)
Horns Rev III (DK)	2016	2018	400 MW	8 MW	16 m	30 km	770 DKR	103.6	117.6
East Anglia I (UK)	2016	2019	714 MW	7 MW	36 m	55 km	119.9 GBP	140.3	140.3
Vesterhav Syd & Nord (DK)	2017	2019	350 MW	TBC	20 m	6 km	475 DKR	63.9	72.9
Borssele I&II (NL)	2017	2019	700 MW	8 MW	26 m	31 km	72.7 EUR	72.7	86.7
Kriegers Flak (DK)	2017	2020	600 MW	TBC	22 m	25 km	372 DKR	50.0	64.0
Borssele III&IV (NL)	2018	2020	680 MW	8 MW	26 m	36 km	54.5 EUR	54.5	68.5

It is important to note that many of the projects included in the analysis have not yet been built or reached FID. Engagement with relevant industry stakeholders suggests that there is high confidence that the projects will be constructed and operated according to the strike prices derived. However, other stakeholders have also voiced concerns over the downward pressure on suppliers and favourable market economics at present, which may not be sustainable long-term drivers of cost reduction. As such, a level of cautious optimism should be applied until greater certainty is evident.

¹⁷ €14/MWh derived from €12-15/MWh range suggested by NERA Consulting. 2016. *Auctions and Bidding Strategy for Offshore Wind*, available at http://www.nera.com/content/dam/nera/publications/2016/PUB_Offshore_Wind_A4_0916.pdf and €14/MWh used by BVG Associates in <http://www.offshorewind.biz/2016/10/28/borssele-tender-revealed/>

¹⁸ €80/MWh target by 2025 set by WindEurope and a group of 11 industry players (Adwen, EDPR, Eneco, E.On, GE, Iberdrola, MHI-Vestas, RWE Innogy, Siemens, Statoil, Vattenfall). €80/MWh including grid connection is expected to equate to ~€66/MWh excluding grid connection.

¹⁹ €14/MWh added to tariff of Dutch and Danish projects (excl. Vesterhav Syd & Nord) to account for development and grid connection costs. Lower uplift of €9/MWh applied to Vesterhav Syd & Nord to account for near-shore location, which will reduce grid connection costs.

Cost reduction drivers

The level of cost reduction achieved to date is a major success story for the offshore wind industry, a sign of the sector's maturity and proving that it is on track to become a low cost and mainstream energy technology. The drivers of this cost reduction are diverse and wide-ranging. A non-exhaustive list of some of the key drivers includes:

- **Scale effects:**
 - Larger individual projects
 - Larger project portfolios
 - Project clusters
 - Cumulative market size
 - Industrialisation and standardisation
 - Higher buying power for some key players
- **Technology innovation:**
 - *Turbines:* Higher capacity rating and larger rotor diameter; high availability; high load factors
 - *Foundations:* XL monopiles
 - *Electrical systems:* 66kV intra-array cables; optimised HVAC and HVDC transmission
 - *Installation:* Bespoke installation vessels
 - *O&M:* Bespoke access vessels; optimised O&M strategies
 - *AEP:* Reduced losses and higher yields
- **Competition:**
 - Competition between projects and developers for limited contracts
 - Top-down pressure on price pushed down through the supply chain
 - Larger, more competitive supply chain, with competition across the industry structure
- **Learning by doing:**
 - Greater experience and confidence from contractors
 - Less conservative pricing strategies
- **Financing:**
 - Offshore wind now considered a bankable asset class
 - Lower risk perception leading to preferential lending rates (lower WACC)
 - Innovative financing models, including a more diverse range of investors
- **Market economics:**
 - Low interest rates
 - Low steel and oil prices
 - Less competition from other sectors (e.g. downturn in vessel activity for oil and gas)
- **Project development de-risking:**
 - Site development activities (e.g. consent, permitting, site data) undertaken by government has reduced project and investment risk for developers
- **Site conditions:**
 - Projects in recent tenders have benefitted from close proximity to shore and/or shallow water depths
 - High wind speeds and larger turbines are delivering higher load factors

Further cost reduction is expected in the coming years, particularly as more countries transition to competitive tendering systems. It is acknowledged that several drivers listed above may not prevail over the long-term. For example, more challenging site conditions and changing macroeconomic forces can put an upward pressure on costs. The cost reduction observed in Europe is also unlikely to be directly transferrable to emerging markets, at least in the near term. Nevertheless, prevailing trends suggest that, as the industry continues to mature, several drivers will be re-enforced. This will be equally applicable to emerging offshore wind markets, provided suitable policy and regulatory frameworks are in place.

3 POLICY & REGULATION

Government policy is critical to stimulating offshore wind development. The growth of the industry over the past two decades has been underpinned by supportive policy frameworks that have catalysed growth in early mover markets and are beginning to embed themselves in new emerging markets. Over this period policies have evolved to meet the needs of the industry and adapted to changing political and market environments. Notable recent trends include the introduction of competitive auction systems (e.g. UK, Netherlands, Denmark) and the transition to centralised development models (e.g. Denmark, Netherlands, Germany).

No single policy framework can be identified as the optimal approach to supporting offshore wind development. A variety of different approaches have been adopted by different countries, with varying degrees of success. Although the importance of local context must be emphasised, some clear examples of best practice and lessons learned can be identified. This section aims to extract these lessons learned through six key policy areas:

- **Market scale and visibility:** Target-setting and market signals to provide long-term industry confidence
- **Site development:** Site identification, leasing, surveying, and consenting
- **Grid connection:** Provision of electrical infrastructure assets
- **Incentive mechanisms:** Remuneration support to ensure project profitability and incentivise industry investment
- **Supply chain development:** Infrastructure investment and business support to develop and maintain a strong local supply chain
- **Innovation support:** R&D initiatives to accelerate the commercialisation of cost-cutting technology innovation

The following sections explore the different approaches that have been adopted in each of these areas, using case study examples to highlight examples of successful policy interventions. Three primary country case studies have been assessed – the United Kingdom, Germany, and the Netherlands – with other country examples highlighted where relevant to capture the breadth of policy measures and approaches observed across the industry. The findings have been developed through a combination of literature review and a series of interviews with key industry stakeholders.

3.1 MARKET SCALE AND VISIBILITY

- **Offshore wind policy objectives should form part of a country’s long-term energy strategy**
- **Visibility is needed over long time horizons**
- **Ambitious targets can catalyse the industry, but need to be integrated within, and supported by, the wider policy framework**
- **Short to medium-term roadmaps can hedge against long-term uncertainty**
- **Stakeholder engagement can support buy-in and longevity for national deployment strategies**

Engagement with industry stakeholders suggests that market scale and visibility is widely considered the most important factor in stimulating industry growth. Sufficient market scale is essential in providing the volume of deployment necessary to maintain a strong and competitive supply chain and achieve economies of scale, while long-term visibility is vital in allowing developers, suppliers, regulators, and other stakeholders to plan and make necessary investment decisions. This long-term visibility is arguably more critical to offshore wind than other renewable energy technologies given the long development timescales for offshore wind project development (typically ~7-10 years) and the high cost of the supporting infrastructure required (e.g. ports, vessels, grid). Indeed, these timescales often exceed those of conventional political cycles, which creates challenges in maintaining accountability and stability for long-term policy goals. However, a number of tools exist for policy makers to send market signals that can provide confidence to industry players and stimulate investment.

3.1.1 Policy tools

International policy drivers

Fundamental to creating long-term visibility of market scale is the need to integrate offshore wind within a country’s broader energy strategy. This typically stems from a series of top-down drivers, including decarbonisation, renewable energy generation, energy security, and industrial strategy goals. From a decarbonisation perspective, emission reduction targets have been outlined in international climate agreements (e.g. Paris Agreement), which have informed carbon reduction at regional (e.g. EU legislation) and national level (e.g. NDCs; UK Climate Change Act). Decarbonisation targets are typically set over long time horizons (e.g. out to 2050), supported by interim milestones at regular, often decadal, intervals. This clear long-term pathway combined with near-term goals enables countries to adopt suitable national energy strategies to meet decarbonisation and renewable energy targets.

In addition and where applicable, grid interconnection targets can assist in providing increased visibility. The EU has set a target of 10% of interconnection capacity between neighbouring countries of their installed electricity production capacity by 2020, with an increase to 15% by 2030 proposed. Interconnection targets are likely to further boost the case for offshore wind, which could play a key role in a future meshed North Sea grid.



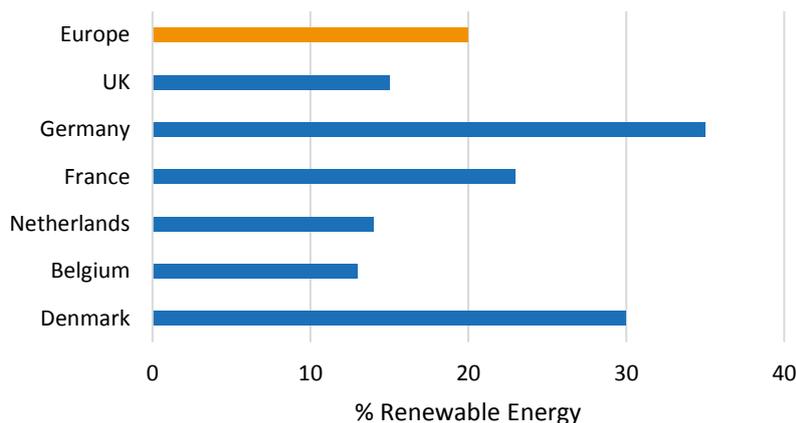
Box 1: European Commission Renewable Energy Directive

EU Directive 2009/28/EC is largely seen as having been a key driver in the development of offshore wind in Europe in recent years. The Directive contained binding renewable energy targets at Member State level and required the development of National Renewable Energy Action Plans setting out the individual technologies expected to contribute to the attainment of the 2020 target at national level. Looking ahead to 2030, the recast Directive proposed as part of the 2016 Winter Package sees the shift from individual nationally binding targets towards an overall EU target (27% renewable energy by 2030). Given that the recast Directive has yet to be negotiated and that the mechanics of how the Directive will work in practice in terms of individual Member State contributions is still unclear, industry perceives a reduced level of certainty about future developments.

National energy strategies

A long-term vision and commitment to increasing electricity generation from renewable energy sources is vital to the development of a coherent national energy policy. A clear national strategy sends a powerful signal to the market that there will be ongoing support for renewable energy technologies. Germany and Denmark, in particular, have adopted progressive energy strategies to transition towards an increasing share of electricity from renewables, which is evident through higher renewable energy targets than other neighbouring offshore wind markets (Figure 6; Germany case study in Box 2). This contrasts to other European countries, where a lack of a clear and consistent energy policy has stalled growth (e.g. Spain).

Figure 6: Target share of renewable energy by 2020²⁰



However, providing long-term technology-specific visibility can be challenging for governments, who may prefer greater flexibility and an ability to challenge industries to demonstrate their value to consumers. Some countries, such as the UK, have adopted a more free-market approach, with groups of technologies competing against each other to win subsidy contracts (albeit grouped by technology maturity). Others, such as the Netherlands, have been more prescriptive on the level of deployment expected from offshore wind, and have introduced ring-fenced support in subsidy auction to guarantee a minimum level of installed capacity. However, this is typically over shorter timescales, reflecting a trade-off that governments need to make between the level of certainty and the degree of visibility provided. In many cases, industry will have a preference for greater certainty over the near term than lower certainty over the long term. In some cases, continued support over the long-term can be made contingent on achieving particular price points, which hedges government risk and continues to incentivise cost reduction.

²⁰ European Commission. 2016. *Renewable energy in the EU*. Available at: <http://ec.europa.eu/eurostat/documents/2995521/7155577/8-10022016-AP-EN.pdf/38bf822f-8adf-4e54-b9c6-87b342ead339>



Box 2: Energiewende

In Germany, the government has outlined a clear national energy strategy to transition away from fossil fuel and nuclear power towards an energy system dominated by renewable energy sources. The Renewable Energy Act under the Energiewende policy outlines a goal to achieve 80% renewable electricity generation by 2050, with near term targets of 40-45% by 2025 and 55-60% by 2035. A deployment corridor is assigned to control the amount of renewables coming online each year, with capped auctions to determine winners of subsidy contracts and grid permits.

The adoption of these targets has acted as a driver for investment in renewables, including offshore wind, which can provide higher load factors and provide more operating reserve than other renewable generation sources, such as onshore wind and solar PV. The ‘WindSeeG’ (German Offshore Wind Act) has set targets of 6.5 GW by 2020 and 15 GW by 2030, supported by a marine spatial plan and federal grid plan to identify sites and plan grid connection phasing. Although these deployment volumes mark a scaling back from original targets, Germany is currently one of the world’s fastest growing offshore wind markets and has been particularly successful in securing considerable market share for leading domestic suppliers, such as Siemens and Senvion, as well as regenerating several ports, which have served as hubs for offshore wind activity (see section 3.5).

Although proponents of offshore wind are calling for more ambitious offshore wind targets and the transition to a centralised auction based system has been disruptive to several developers, the visibility provided by the Offshore Wind Energy Act over the planned capacity of auction rounds up to 2030 will provide greater certainty for project developers and suppliers to plan accordingly. The offshore wind energy corridor includes 500 MW per year tendered between 2021 and 2022, 700 MW between 2023 and 2025, and 840 MW annually from 2026 onwards, steadily increasing the level of offshore wind capacity as onshore grid constraints are relaxed.

Dedicated offshore wind policies

For a number of European countries, offshore wind is seen as an important pillar to achieving renewable energy targets. This has manifested itself through a variety of mechanisms to provide confidence in the scale of the market and create an attractive environment for inward investment, including:

- **Deployment targets:** The simplest form of target-setting, this sets a target installed capacity over a given timeline. Provided these are enforced and tied to appropriate supporting policy, targets give a clear indication to industry over the anticipated scale of deployment.
 - **Example:** Germany has set a target of 6.5 GW by 2020 and 15 GW by 2030.
- **Site identification and leasing:** Identifying suitable sites for offshore wind development, which may be auctioned and leased to prospective developers, sends a strong signal to the market that future growth will follow. However, again, site leasing must be accompanied by suitable policy and regulatory frameworks to deliver on expectation.
 - **Example:** The Crown Estate has ran several leasing rounds for sites in UK waters with a cumulative capacity of over 40 GW.
 - **Example:** Following the UK model, Chinese Taipei has released 36 sites for offshore wind development with a total capacity of ~15.4 GW.
- **Capped auctions:** With the transition to competitive auction systems, a cap is allocated to constrain deployment, either as a straightforward cap on capacity (regardless of price) or as a cap on the allocated budget to support deployment (where price impacts the level of deployment possible).
 - **Example:** The Netherlands have outlined a roadmap to achieve their 2023 offshore wind target, supported by site auctions capped at ~700 MW per year.

- **Example:** The UK provides near and medium-term visibility through the size of the Levy Control Framework, a fixed budget on the support available to energy technologies through the allocation of Contracts for Difference. The UK government has allocated funding to support 10 GW of total installed capacity by 2020 and committed to support an additional 10 GW by 2030, provided certain price points are met.
- **Legislation:** Government legislation can include requirements for a minimum amount of offshore wind electricity to be procured from utilities.
 - **Example:** Massachusetts has enacted an energy bill that requires state utilities to procure 1.6 GW of offshore wind power by 2027.

It should be noted that these are not mutually exclusive and are most effective in combination. For example, national deployment targets can be supported by leasing processes and relevant regulation and delivered using capacity auctions.

Offshore wind market scale

The high capital expenditure in developing and constructing offshore wind farms requires a given level of market scale to justify investment costs, deliver economies of scale, and ensure sufficient competition between industry players. Steadily increasing deployment and forward pipelines in Europe have been one of the primary drivers of cost reduction, which is aided by concentrated development within the North Sea and neighbouring regions. As governments enforce downward pressure on price and shift to competitive auction-based systems, maintaining consistent deployment levels will be critical in continuing the downward cost reduction trend.

Industry body WindEurope are calling for at least 4 GW annual installed capacity across the European region to maintain a competitive supply chain and encourage continued investment in innovation. However, analysis of deployment in leading markets suggests that a deployment gap of ~1 GW could exist without increased political commitment (Table 2). Greater ambition is therefore required from policy makers to outline higher deployment volume over the years to 2030.

Table 2. Anticipated post-2020 annual installed capacity across Europe

Country	Post-2020 annual installed capacity	Comment
UK	~1,000 MW	Based on UK Government commitment for 10 GW from 2020-2030.
Germany	500-840 MW	500 MW/yr in 2021-22; 700 MW/yr in 2023-25; 840 MW/yr in 2026-2030.
Netherlands	700-1000 MW	700 MW/yr from 2018-2023; ~1 GW/yr from 2023-2030.
Denmark	0-300 MW	Based on current pipeline to 2020; no firm commitments.
Belgium	0-300 MW	Based on current pipeline to 2020; no firm commitments.
France	~500-800 MW	3,000 MW from 2017-2023; 6,000 MW from 2023-2030.
Other Europe	TBC	No firm commitments.
TOTAL	2,700-4,200 MW	

Challenges of market scale are even more acute in emerging markets, where deployment levels are expected to be considerably lower. This is particularly evident in more isolated markets, such as Japan and Chinese Taipei, where there are limited opportunities to leverage neighbouring infrastructure and supply chains. Cooperation between East Asian countries could be critical to industry success, particularly in leveraging the growing Chinese offshore wind market. Likewise, the USA has the potential to reach volumes of scale rivalling those seen in Europe, but inter-state cooperation will be vital to delivering costs that are acceptable to consumers, particularly in the near term. Without suitable coordination and collaboration, these emerging markets will be faced with higher project costs.

3.1.2 Lessons learned

Ambitious targets can catalyse the industry, but need to be integrated within, and supported by, the wider policy framework

Targets can help to inform regulation and importantly provide the market with a clear indication of a government's intent. The availability of credible targets play an important role in giving the industry the confidence that there is the political will to deploy the technology. However, just as ambitious targets can stimulate industry growth, downgrading targets can negatively impact on investor confidence in the sector. Downward revisions to offshore wind targets have occurred across a number of markets:

- **EU:** It is estimated that the cumulative total for offshore wind of 43.3GW by 2020 contained in the EU Member States original National Renewable Energy Action Plans will not be achieved with figures closer to 24GW expected by 2020.
- **UK:** The UK has downgraded its original 2020 target from ~18 GW to 10 GW. Engagement with industry stakeholders also suggested that the scale of the Round 3 leasing round was overly ambitious, setting unrealistic expectations for the sector in its formative years.
- **Germany:** Germany has downgraded its original targets of 10 GW by 2020 and 30 GW by 2030 to 6.5 GW by 2020 and 15 GW by 2030.
- **France:** Following 3 leasing rounds, the most recent French multi-annual energy programme sets a target of 3 GW of fixed offshore wind to be installed by end 2023, representing a downgrade of the 2009 target of 6 GW by 2020.
- **China:** China has downgraded its targets from 5 GW by 2015 and 30 GW by 2020 to 5 GW by 2020 and 30 GW by 2030. Even these latest targets have been, or are expected to be, missed.

These downgrades have been caused by a number of factors, including higher than expected project costs, permitting and grid connection delays, and an underappreciation of the complexity and challenges of building offshore wind farms (i.e. an expectation that offshore wind could be built out at the same rate as onshore wind). However, most critically, targets were not accompanied by suitable policy and regulatory frameworks or tied to national energy strategies. Targets in themselves are rarely sufficient to drive increased deployment in the absence of supporting policy measures, such as incentive mechanisms and appropriate legislation to enable projects to be constructed on time and on budget. The various elements that make up a supportive policy framework are discussed in the subsequent report sections (3.2 to 3.6).

Steady, phased deployment is more effective than periods of boom and bust

While high deployment volume is a core driver of cost reduction, policy makers need to ensure that roll out is spread evenly across delivery years. A lack of coordinated planning can result in peak periods of construction which lead to supply chain bottlenecks and associated price pinches. Conversely, periods of low activity can derail supply chain confidence and investment. Such volatility is unfavourable for both industry and governments. As such, tendering rounds should be phased with necessary delivery milestones to provide a manageable build out schedule, as well as coincide with planned grid network reinforcements.

Coordination should also be encouraged between countries to manage deployment schedules. In Europe, nine North Sea countries have signed a cooperation agreement to collaborate on several regulatory issues, including coordination of national deployment strategies to mitigate supply chain bottlenecks in the region²¹.

²¹ Government of Netherlands. 2016. *Collaboration between countries in the North Sea region for more wind farms at a lower cost*. Available at: <https://www.government.nl/latest/news/2016/06/06/collaboration-between-countries-in-the-north-sea-region-for-more-wind-farms-at-a-lower-cost>

Short to medium-term roadmaps can hedge against long-term uncertainty

While long-term visibility is always a primary policy request from industry, these timescales often exceed political cycles and are difficult to enforce with legally binding commitments. However, short to medium term certainty can often be more effective if this includes a clear roadmap with appropriate policy levers to meet deployment targets. This can require government actors to take on more up-front development risk to reduce the development timescales and investment risk for project developers (i.e. centralised development model). In the Netherlands, for example, the government has outlined a clear 5 year pathway with 700 MW annual installed capacity up to 2023, with accompanying support mechanisms and all site permits in place (see Box 3). Despite uncertainty beyond 2023, the level of scale over a 5 year period is sufficient to encourage developers and suppliers to invest in the market. These nearer term roadmaps are arguably more challenging to adopt with a decentralised development model, where long development timescales (~7-10 years) require greater long-term certainty to initiate developer investment in site development.

Stakeholder buy-in can support policy stability

While international, inter-regional, and national framework policies are key, in-country regional authorities and stakeholders also have an important role to play in engaging with policy development and target setting. Agreeing a suitable level of deployment with industry players is therefore crucial in setting targets that are both ambitious but realistic. Maximising buy-in from a wide range of stakeholders across government departments can mitigate risk from policy changes, particularly if long-term targets exceed political election cycles.

Deployment can be linked to cost reduction targets

While setting targets and committing to support deployment provides confidence to reduce investment risk for developers, governments can limit their own risk exposure by linking deployment targets to cost reduction goals. This can be an effective means of challenging the industry to reduce costs and driving the sector towards a subsidy free future. For example, the UK government has challenged the industry with reaching £105/MWh (equiv. €123/MWh) by 2021 and £85/MWh (equiv. €100/MWh) by 2026, with continued support for an additional ~10 GW of installed capacity from 2020 to 2030 under the Levy Control Framework if these price points are achieved.

Box 3: Netherlands offshore wind strategy

Driven by the Dutch Energy Agreement, which identified an important role for offshore wind in meeting national decarbonisation targets, the Netherlands have introduced a roadmap for offshore wind development out to 2023. The roadmap includes annual tender rounds for ~700 MW capacity from 2015-2019, which will enable the Netherlands to meet its offshore wind target of 4.5 GW by 2023.

The approach adopted by the Netherlands incorporates many of the lessons learned listed above, following an extensive industry consultation led by the Ministries of Economic Affairs and Infrastructure and Environment, the Netherlands Enterprise Agency (RVO.nl) and Rijkswaterstaat, to design an appropriate policy and regulatory framework for offshore wind development. The roadmap provides clear visibility for the sector up to 2023 with clearly defined market scale spread evenly over a 5 year programme. This guaranteed base level of deployment ensures stability for the industry, allowing developers and suppliers to plan accordingly.

Targets have also been linked to a robust and transparent policy framework, including timely permitting and grid connection, based on the Danish development model in which the government takes on the cost and risk of site development. Tenders are launched for specific offshore sites, maximising competition to drive down costs.

The Dutch government outlined a 40% cost reduction target for the Dutch offshore wind sector, relative to the previous tariff level, with an initial price cap of €124/MWh falling steadily to €100/MWh for the 2019 auction. However, this was surpassed in the first auction round for Borssele I and II sites, with DONG Energy winning with a strike price of €72.7/MWh, 41% below the price cap. The second auction round exceeded this further, won by the Blauwwind II consortium including Shell, Eneco, Van Oord, and Mitsubishi/DGE with a landmark low strike price of €54.5/MWh, 54% below the price cap.

The low strike prices attained in the first two auction rounds are expected to deliver considerable reductions to public expenditure, with ~€2.7bn of savings anticipated in Borssele I&II and €~4.7bn of savings in Borssele III&IV. Public support for Borssele III&IV is expected to amount to just €300m over the first 7 years of operation, with the wind farm operating without subsidies for the final 18 years of its lifetime (assuming rising wholesale prices).

Another source of cost savings is expected from the standardisation of 5 equal 700 MW substations designed by grid operator Tennet, who will have responsibility for building and operating the assets.

The project pipeline beyond 2023 is still unclear, but Dutch authorities have signalled intent to construct ~1 GW per year from 2023 to 2030, according to the Ministry of Economic Affairs' 'Energy Agenda'. The next roadmap may also consider phasing out subsidies for offshore wind by 2026.



Source: RVO

Year	Power	Wind Farm Zone	Price cap (eurocent/kWh)
2015	700 MW	Borssele Wind Farm Zone, Wind Farm Site I and II	12.400
2016	680 MW	Borssele Wind Farm Zone, Wind Farm Site III and IV	11.975
2017	700 MW	Wind Farm Zone Hollandse Kust (zuid)	10.750
2018	700 MW	Wind Farm Zone Hollandse Kust (zuid)	10.325
2019	700 MW	Wind Farm Zone Hollandse Kust (noord)	10.000

Source: RVO

3.2 SITE DEVELOPMENT

- **The transition to competitive auctions demands greater government site de-risking activities**
- **Spatial planning is critical to selecting the best development zones and mitigating consenting challenges**
- **Consenting regimes should provide a clear framework with defined timelines, coordinated responsibilities, and front-ended consultation**
- **‘One-stop-shop’ entities that bundle permits into a single process can streamline the permitting process and mitigate stakeholder conflicts**
- **Greater flexibility in the consenting envelope can future-proof sites for the adoption of innovative, low cost technologies**
- **Site extensions are a cost-effective and low risk means of deploying additional offshore wind capacity**
- **Scientific research studies can be used to inform and improve consenting processes**
- **Cumulative environmental impacts are an increasingly important issue for the industry**

Site development is a fundamental step in the development of an offshore wind farm. Extensive in its scope, site development comprises several stages, including site identification, site surveying, leasing, consenting, grid permitting, and eventually the construction of the transmission infrastructure. Given the number of stages and stakeholders involved, site development can often be a time-intensive process, often between 7 to 10 years, at a cost of up to £70m (equiv. €82m) per wind farm. Getting it right is therefore essential to maximising the success of offshore wind project developments.

A sequence is generally followed beginning with marine spatial planning to identify suitable zones or specific sites, before more detailed site surveys are conducted to confirm the suitability of the sites and inform site layout and technology options. Once the parties involved are confident of the site’s viability from a financial, environmental, and technical perspective, site consent and relevant permits need to be obtained before advancing to final investment and wind farm construction (provided a subsidy contract is obtained).

3.2.1 Policy tools

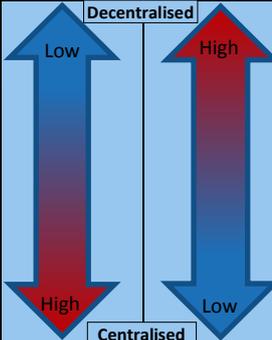
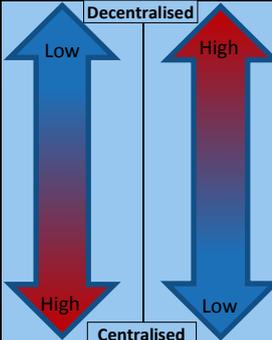
Three typical models have been evident in offshore wind site development to date:

- **Centralised model:** Government bears the majority of the up-front financial risk and undertakes the site identification, surveying, consenting, and grid permitting prior to auctioning the site. In such a system, the developer only enters into the process at the pre-construction phase, by submitting a bid for a specific project site. Whilst attractive for developers from a de-risking perspective, it can limit the scope to demonstrate competitive advantage, with some industry players preferring to obtain greater control of the site selection and development process.
 - **Examples:** Denmark; Netherlands.
- **Decentralised model:** Developer takes the lead in undertaking site surveys, acquiring grid permits and consent, and designing and constructing the electrical infrastructure. Such an approach involves lower risk and up-front cost for governments, but this will be reflected in higher strike prices once contracts are awarded. For developers, a decentralised approach can be preferable in the level of control and opportunities to demonstrate competitive advantage, but can introduce significantly higher up-front risk for developers, particularly if allocation is constrained through auction-based remuneration systems.
 - **Examples:** United Kingdom; China; Japan.

- Hybrid model:** Government takes control of some, but not all items of the site development process. For example, government may undertake site identification, initial site surveying, and grid permitting, but require the developer to obtain full consent and further site surveys.
 - Examples:** Germany; France (Round 3 projects).

A summary of the site development approaches undertaken in the UK, Netherlands, and Germany is shown in Table 3, below, and a more detailed overview can be found in Box 4.

Table 3. Approaches to offshore wind site development

	Zone identification	Site selection	Site investigation	Consenting/ permitting	Grid application	Grid design & construction	Government risk/control	Developer risk/control
	Crown Estate	Developer	Developer	Developer via PINs	Developer / National Grid	Developer/ OFTO		
 EEG 2014	Government	Developer	Developer	Developer via BSH	TSO	TSO		
 EEG 2017	Government	Government	Government	Developer via BSH	TSO	TSO		
	Government	Government	Government	Government	Government / TSO	TSO		

Note: Green indicates government/TSO responsibility; orange indicates developer's responsibility. The sequence of steps can vary by country (see below).

It should be noted that each model has its advantages and the approach taken by governments will largely depend on local context, national objectives, and a government's willingness to share risk. However, particularly with the transition towards competitive auction systems, there has been a recent shift from decentralised to more centralised approaches. The centralised approach, pioneered by Denmark ('the Danish model'), whereby the government develop a site to the pre-construction phase before auctioning to prospective developers, has also been adopted by the Netherlands.

Similar models are also in transition elsewhere in Europe. For example, Germany is currently moving towards a more centralised approach in which governments will auction specific sites, as opposed to the open-door method adopted previously. However, in Germany consenting remains the responsibility of the developer and is only considered after contract award. Belgium is also making steps towards more centralised procedures.

The UK, the market leader in deployment to date, is so far maintaining a more decentralised approach, with greater responsibility and up-front risk for developers. However, the transition to the auction-based CfD regime has increased allocation and price risk considerably, meaning that more up-front de-risking may be required by public bodies in future leasing rounds. However, the free-market approach adopted by the UK, in which energy technologies must compete on a level playing field, may not align with a fully centralised model.

Changing regulatory frameworks can also be a complex process that needs to be managed carefully to minimise losses from sunk costs under existing regimes. For example, in both the Netherlands and Germany several developers have had their site leases withdrawn in order to facilitate the transition to centralised auction systems. These developers have lost considerable investment from site acquisition and development activities, with no compensation available to offset these losses. Such policy changes can undermine investor confidence and be disruptive to sector growth.

Box 4: Summary of site development responsibilities across selected EU jurisdictions



United Kingdom:



(i) The Crown Estate, which owns the rights to the UK seabed, identifies areas that qualify for offshore wind development. These large spatial zones are selected based on site characteristics (e.g. wind speed, seabed conditions, water depth) and known site constraints (e.g. grid connection, environmental impact). (ii) Developer submits bids for exclusivity of a given zone. (iii) Developer selects specific area within the zone and reach an agreement for lease with the Crown Estate. The term of the lease is negotiated on a project-by-project basis, with fees typically paid based on power production. (iv) Developers conduct site investigations to develop an accurate understanding of the site characteristics and determine technical and financial feasibility. (v) In England and Wales, consent and permitting applications are submitted to the planning inspectorate (PINS). This entails a clearly prescribed stage gated process, with clearly defined timelines. In Scotland, applications are assessed by Marine Scotland under the Section 36 process. (vi) Once consented and fully permitted, the project is eligible for a ROC (pre-2017) or to compete for a subsidy contract in CfD auctions (2016 onwards).



Germany (old regime – EEG 2014):



The German model currently follows a similar process to the UK. (i) BSH release site zones for prospective developers to acquire through auction. Conservation zones and other constraints (e.g. shipping routes) are excluded. (ii) Developer submits consent application to BSH. (iii) BSH award a lease, with no fee attached. (iii) Developer conducts site investigations. (iii) TSO applies for grid permits. (iv) Developer is eligible for the feed-in tariff (pre-2017) or to enter competitive auction (auctions in 2017-2018; commissioning before 2021).



Germany (new regime – EEG 2017):



The new German approach, for projects commissioning from 2021 onwards, is more centralised, with government taking on more responsibility for developing sites. (i) Sites are selected in advance, according to the nationally coordinated marine spatial plan and offshore grid plan, with a schedule of when these sites will be auctioned. (ii) Site investigations are conducted and passed on to developers ~6 months before the auction. (iii) Developers compete for the sites through an auction process. Winning bidders will get a subsidy contract, grid permits, and the guarantee that the TSO will build and operate the transmission assets. (iv) Once subsidy contract and grid permit are in place, developer can commence the legal process to gain consent (via BSH), with a 12 month period to submit all documents. This accelerated timeframe is possible given that site investigations have largely been completed. (v) Once permitted, developers can commence with wind farm construction.



Netherlands:



The Dutch Government has adopted a highly centralised approach to site development. (i) The Government undertakes the selection of specific project sites, conducts the necessary site investigations, and obtains full consent and grid permits. (ii) Developers compete for sites through an auction process. Winning bidders are awarded a subsidy contract (SDE+) and all necessary permits to progress with wind farm construction.

3.2.2 Site identification and leasing

Selecting the location of an offshore wind farm is one of the key determinants that influences a site’s technical and economic viability, impacting heavily on revenue generation (energy production), capital expenditure (technology design, installation), and operational expenditure (maintenance, repairs). The location of offshore wind sites can also impact on the onshore transmission network and energy system balancing requirements.

Approaches to site identification and leasing

To date there have been different approaches to identify sites or zones for offshore wind development, which have evolved over time across different jurisdictions.

Open-door

With low levels of information on factors such as wind conditions, seabed geology, wave height, and other environmental and human constraints, as well as limited anticipated deployment, government agencies initially adopted an open door approach to site identification. In this approach, developers take the lead in identifying suitable sites and securing agreements for lease with the relevant authorities. This presented a low cost approach for governments at a time when offshore wind was an immature energy technology, and a more flexible approach for developers looking to select the most attractive sites in the industry’s formative years. However, open door approaches have experienced mixed success, with some sites successful in gaining consent relatively quickly, while others have suffered major setbacks from consenting issues.

The setbacks incurred can largely be attributed to the limited information available to select the most appropriate sites. In particular, sites were generally selected based on dominant basic parameters, such as wind speed and water depth, often neglecting key constraints, including ground conditions, grid connection, and environmental sensitivity. In the UK, this led to some notable project failures, including Shell Flats, Scarweather Sands, and Cromer (see Box 6). Given the nascent state of the industry, setbacks are unsurprising, but important lessons were learned in the process in terms of the value of undertaking more work up-front to understand site constraints before significant development expenditure is incurred.

Zoning

With increasing understanding of key parameters and constraints, as well as the application of spatial planning tools (e.g. The Crown Estate’s MaRS tool; BSH’s GeoSpatial tool), countries have been able to take a more strategic approach to site identification²². This has manifested in the establishment of strategic environmental assessments (SEAs) or marine spatial plans (MSPs), which have been used to inform more detailed constraints mapping exercises to designate appropriate zones for offshore wind development. This important first step in the planning process mitigates risk of conflict with competing sea users and enables governments to make informed strategic decisions.

In the zoning approach, the controlling authority designates large offshore zones for prospective developers to acquire through a competitive process²³. Once exclusivity is obtained, developers can select the most appropriate sites for their projects. This approach is favoured by many developers as it allows greater flexibility to pick the sites they deem the most attractive, with the added certainty that several potential constraints have already been evaluated and de-risked.

²² It should be noted that some countries have greater ability to select specific sites than others due to better information or restriction of available space. For example, the Dutch and German coasts in the North Sea have higher restrictions arising from shipping routes, oil & gas, and conservation zones, leaving a smaller area to investigate compared to the UK, which has a far larger coastal area to consider.

²³ In the UK, zones were assigned based on the quality of the proposal (i.e. technical competence, track record, etc.) rather than price. In contrast, in the United States BOEM runs competitive auctions to acquire leases to the seabed, based purely on price.



Box 5: Spatial planning in Germany

Marine and grid spatial plans are essential mechanisms to identify suitable sites by addressing conflicting demands for the seabed and mapping out potential constraints to development. These are often derived from strategic environmental assessments (SEA's), assessments of suitable grid connections, using spatial planning tools and GIS to map data on wind, water depth, seabed geology, conservation zones, shipping lanes, military activity and other potential constraints.

The Federal Maritime and Hydrographic Agency (BSH) is the federal agency overseeing licensing for renewable energy projects in the EEZ in Germany. BSH has recently produced a maritime spatial plan and offshore grid plan to identify the most appropriate sites for offshore wind development, which will ensure timely and efficient offshore transmission extensions and onshore grid reinforcement at least cost to consumers.



Box 6: Spatial planning in the UK

The UK undertook a strategic assessment and constraints mapping exercise when assessing Round 3 sites, which helped to identify 9 development zones with potential for ~26 GW installed capacity. Combined with other development rounds, this brought potential installed capacity to over 40 GW in UK waters, acting as an important catalyst and enabler for offshore wind development in the UK.

However, even past zoning efforts undertaken through SEAs and constraints mapping tools have encountered setbacks from unexpected issues, such as ground conditions, cumulative impacts, and public opposition, resulting in the cancellation of ~7.6 GW of capacity. For example, in the UK, challenging ground conditions led to the cancellation of Atlantic Array (1.2 GW) and Celtic Array (4.2 GW); meanwhile, concerns around cumulative impacts led to the cancellation of Docking Shoal and curtailed capacity for London Array and Race Bank, and public opposition led to the cancellation of Navitus Bay (Table 4).

A further 4 GW is currently at risk in the Firth of Forth following a judicial review of the consent awards. These have produced some important lessons learned for future leasing rounds in better understanding potential constraints at the outset. For example, more extensive and rigorous site investigations and up-front stakeholder engagement can aid the identification and mitigation of potential challenges before considerable development expenditure is made.

Table 4. UK project cancellations

Zone	Round	Capacity (MW)	Status	Reason for cancellation
Cirrus Array (Shell Flats)	Round 1	270	Withdrawn	Environmental impact.
Cromer	Round 1	108	Withdrawn	Environmental impact.
Scarweather Sands	Round 1	108	Withdrawn	Site conditions (geology, wind speed)
Docking Shoal	Round 2	540	Refused	Environmental impact.
London Array II	Round 2	240	Withdrawn	Environmental impact.
Atlantic Array	Round 3	1,200	Withdrawn	Site conditions (geology, water depth)
Celtic Array	Round 3	4,200	Withdrawn	Site conditions (geology)
Navitus Bay	Round 3	970	Refused	Public opposition.

Site-specific

The zoning approach contrasts with a site specific approach in which the relevant government authority identifies specific individual project sites for offshore wind development. This is typically employed in combination with a centralised development model, whereby government bodies undertake the majority of the site development work, including site surveys and acquiring relevant permits, before auctioning to developers at the pre-construction phase. This approach mitigates the risk of not obtaining consent and ensures that developers are well-informed of site conditions before submitting bids, helping to deliver lower strike prices in competitive auctions. Indeed, the effectiveness of this approach has been evident in recent low strike prices awarded in the Netherlands and Denmark.

However, a centralised, site-specific approach is not always favourable for developers, as it can limit opportunities to gain competitive advantage across the project lifecycle. It can also be argued that offshore wind developers are more experienced and better placed to undertake site development activities than government. However, this needs to be balanced against the potential sunk costs if wind farm development falls through.

Another consideration is the level of portfolio risk for developers, which is increased with widespread adoption of centralised site-specific tendering at the pre-construction phase, given the greater uncertainty of achieving success and lack of visibility ahead of contract wins. In contrast, exclusivity to sites under a zoned approach provides greater certainty of developing a portfolio of projects that enables developers to justify investments in dedicated personnel, research and development activities, and developing relationships with local suppliers over a long-term period.

Consultation with industry stakeholders suggests that several developers exhibit a preference for a variety of policy and regulatory frameworks in different markets, which can help to hedge risk and strike a balance between sufficient portfolio size and the ability to compete for de-risked project sites.

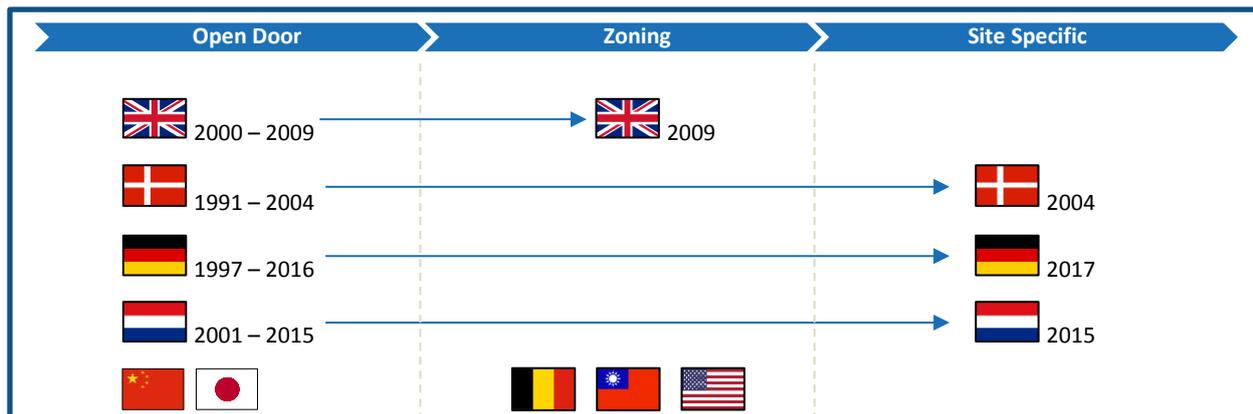
Evolution of approaches to site identification and leasing

As the industry has matured with increasing deployment volumes, open door approaches have generally been phased out in favour of zone and site-specific approaches, which enable greater government control in the site identification process (Figure 7). The UK continues to adopt a zoned approach, given that there remains sufficient volume to meet near term deployment targets. Depending on the UK government's long-term ambitions, further leasing rounds may be required. In the near-term, the UK is supporting extensions to existing projects, which can serve as a low cost and low risk means of adding additional offshore wind capacity.

For countries running new site identification rounds, recent trends display an evolution towards site specific approaches. Both the Netherlands and Germany have now transitioned to site specific tenders based on the perceived benefits of increased coordination and clustering of sites, mirroring the Danish model. This follows the trend towards centralised site development with competitive tendering for subsidy contracts.

In emerging markets, where industry maturity and deployment levels are lower, there continues to be a preference for open door and zoning approaches. China and Japan both employ an open door approach while Chinese Taipei and the United States have adopted a zoning method, similar to the UK (see Box 7).

Figure 7. Evolving approaches to site Identification and leasing



Source: Carbon Trust; adapted from O.Fitch-Roy. 2015²⁴

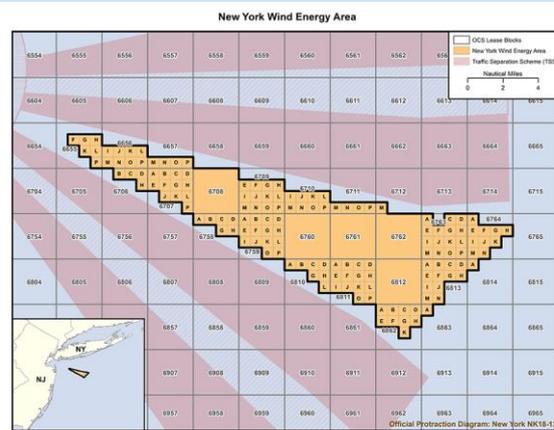


Box 7: Site leasing in the United States

Site leasing in the United States is coordinated and managed by the Bureau of Ocean Energy Management (BOEM), part of the US Department for the Interior (DoI). BOEM liaise with relevant federal agencies and state departments to identify suitable areas for offshore wind development whilst minimising environmental impact and conflict with other activities. Developers can then enter competitive auctions for lease areas, administered by BOEM and assessed on price, to gain exclusivity of sites. Once a lease has been awarded, developers can progress with site investigations and environmental assessments, before obtained the necessary permits to begin construction.

BOEM’s role in identifying and leasing sites has been crucial in stimulating the industry in the US, providing the requisite conditions for commercial developers to obtain site control and pursue project development. To date, BOEM has issued leases covering >1m acres across six US states (Maryland, Massachusetts, New Jersey, New York, Rhode Island and Virginia), resulting in cumulative lease sales of US\$ 58.5m (equiv. €55m).

This includes a lease sale off New York in December 2016, which was won by Statoil for a record high bid of US\$ 42.5m (equiv. €40m). The high demand for the site was partly driven by a New York state target to generate 50% electricity from renewable sources by 2030, but also reflects growing optimism and confidence in the potential for considerable offshore wind development along the US East Coast. New York State have since announced plans to develop 2.4 GW of offshore wind by 2050.



Source: BOEM

²⁴ O, Fitch-Roy. 2015. *An offshore wind union? Diversity and convergence in European offshore wind governance*. Available at: <http://www.tandfonline.com/doi/figure/10.1080/14693062.2015.1117958?scroll=top&needAccess=true>

3.2.3 Site surveys

Site data is key to identifying the right zones or sites. In order to successfully select the most appropriate sites for offshore wind development, responsible government agencies and/or developers must have a comprehensive understanding of the wind conditions, water depth, seabed characteristics, environmental sensitivities, and other constraints. This information is acquired by undertaking site survey and investigations. High quality site data can improve the confidence in the long-term performance of a site for project developers, but importantly can also increase the confidence of lenders and investors in the projects, which can help to reduce the cost of finance. Poor quality site data or a lack of constraint mapping can have detrimental impacts on project development.

Box 8: Floating LiDAR as a more cost-effective alternative to traditional metrological masts

Given the higher risk exposure during the project development phase and importance of obtaining high quality site data, a significant amount of innovation has been undertaken to improve the accuracy and lower the cost of gathering data. One notable technological development is the use of floating LiDAR to capture wind speed data, as opposed to conventional meteorological masts.

Traditional meteorological masts are fixed to the seafloor with large steel foundations and require expensive jack-up barges to install, costing €10-20m per mast and require a number of years to deploy due to permitting and design requirements. They are only able to measure wind speeds and directions at a single point in a site, and tend to be restricted to measurement altitude of up to ~100m above sea level.

Floating LiDAR, however, is a low cost alternative to obtaining accurate wind speed measurement. The technology allows for wind speed measurement at altitudes of up to 200m, which has multiple technical benefits, including wind speed measurements across the whole rotor swept area of a potential turbine, which would reduce the uncertainty of measurements obtained. The floating LiDAR platforms can be towed to a site and anchored, which enables very fast deployment (months rather than years) and significantly reduces the complexity of installation.



Source: Left: Installation of a met mast (Fugro Seacore); Right: Installation of a floating lidar device (RVO.nl).

In line with the transition to more centralised development models, there has been an increasing shift to government taking the lead on site data collection, undertaking site surveys and making data publically available in order to de-risk the sites for prospective developers. The key driver for this approach has been to (i) increase control and knowledge of the sites; (ii) reduce up-front risk and development expenditure for developers; and (iii) supply prospective developers with accurate site data in advance of auctions. In reducing uncertainty of site conditions and consent award, this can enable developers to adopt a less conservative pricing strategy, leading to lower strike prices and, ultimately, lower costs to consumers. For example, in the Netherlands, government agency RVO undertakes all site surveys and makes the data publically available. Germany are also transitioning to this approach, under the coordination and management of BSH.

3.2.4 Consenting and permitting

This section provides an overview of consenting policy and responsible entities, including how the interests of competing maritime activities are managed and environmental impact assessments are conducted.

Consenting and permitting process

Consenting is typically a long and often complicated process. Consenting for offshore wind can typically take between 3-7 years and bear significant capital requirements, with costs up to £30m (equiv. €35m), although 2014 analysis by Renewable UK suggests consenting costs typically range between £1.5m to £10m (equiv. €1.8m to 11.7m) across UK sites, equating to £11k - £20k/MW (equiv. €13k – €23.5k/MW)²⁵. Although not a large cost in the context of the full project, which can range from £1-2bn (equiv. €1.2 – 2.3bn) for large-scale offshore wind farms (~£2-3m/MW) (equiv. €2.3 -3.5m/MW), this level of expenditure in the development stage is high risk, representing a potentially large sunk cost if consent is declined. The high cost and risk has pushed some governments to support developers by either taking on full (e.g. Netherlands) or partial (e.g. Germany) responsibility for consenting.

The same EU Framework policies and Directives drive consenting across EU countries. Core policies include the *Strategic Environmental Assessment directive 2001/42/EC*, the *Environmental Impact Assessment directive 2011/92/EU*, *Habitats Directive 92/43/EEC*, *Birds Directive 2009/147/EC*, and the Marine Strategy Framework. Regulation across European countries therefore holds many similarities (e.g. environmental monitoring requirements, approval process, and type of stakeholders involved), but the approach to implementation differs.

The approach differs across jurisdictions in terms of the procedural requirements to acquire relevant permitting and the responsibility of who does so. In the UK, project developers are obliged to undertake the necessary steps to obtain consent, with different procedures in England and Wales, where the planning inspectorate (PINS) awards consent through the ‘Development Consent Orders’ (DCO) process, to in Scotland, where Marine Scotland award consent through the Section 36 process.

In the Netherlands, the Dutch Government obtains consent prior to site tendering, with auction winners receiving the necessary construction permit and subsidy contract. This differs again from the newly adopted approach in Germany, where government undertakes an element of pre-consent during site selection, but project developers are required to obtain full consent following the auction process, when there is greater certainty of the project going forward. Germany also apply stricter requirements on piling noise during construction and the thermal impact of electric cabling.

Arguably, regardless of the nuances between jurisdictions, the most important consideration for any consenting and permitting policy is to provide clarity and transparency for project developers, with clearly defined timelines for the submission, review, and decisions relating to consenting applications.

Evolution of consenting and permitting process

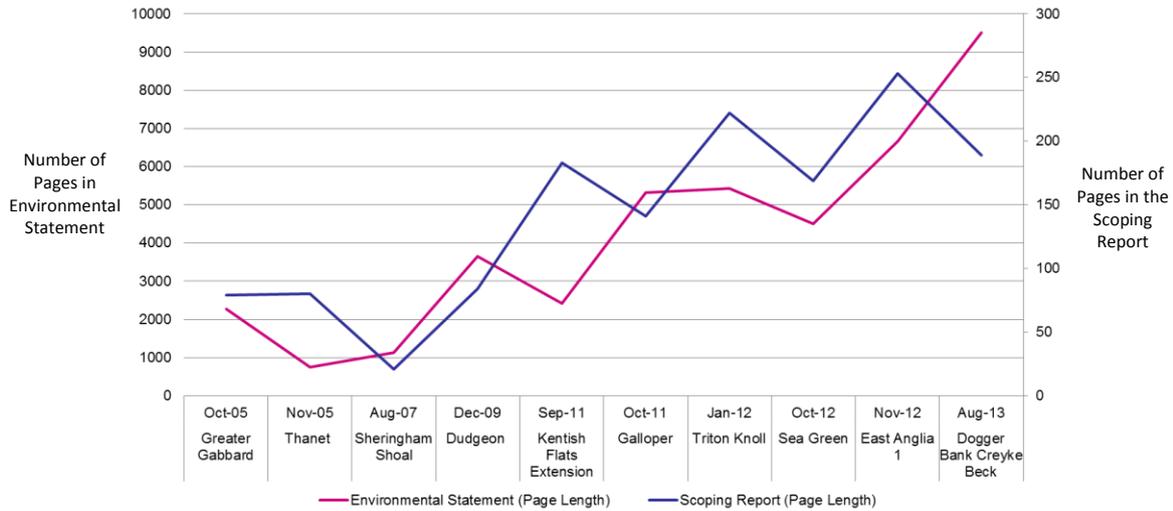
The level of effort and size of environmental statements is increasing significantly, suggesting limited learning is being fed through. Recent debates suggest the level at which the precautionary principle is applied may be too great, in particular for projects that carry inherent uncertainty and impacts are assessed on limited evidence and multiple assumptions²⁶. This has resulted in a significant increase of effort and size of consent applications, increasing the administrative burden on all parties.

²⁵ RenewableUK. 2014. *Managing Regulatory and Consenting Costs for Offshore Wind*. Available at: <http://ruk.pixl8-hosting.co.uk/en/publications/index.cfm/managing-regulatory-consenting-costs-offshore-wind>

²⁶ Ibid.

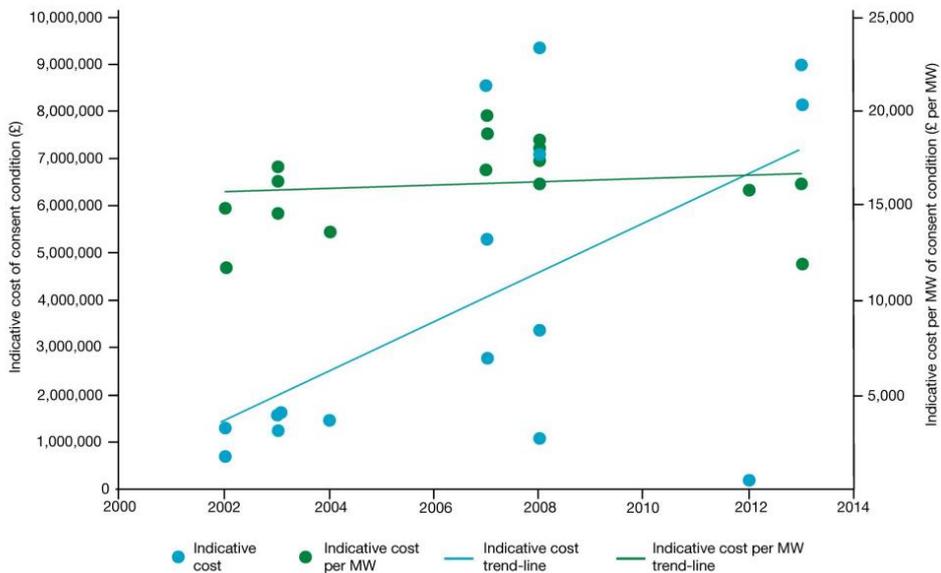
Figure 8 demonstrates the increase in size of environmental statements and scoping reports over time in the UK – a trend confirmed in other front runner countries through stakeholder interviews. Figure 9 demonstrates that despite the increasing size of wind farms the cost for consenting has not decreased on a per MW basis, demonstrating that limited learnings have fed through.

Figure 8. Trends in UK Offshore Wind Environmental Statements



Source: The Crown Estate. Upcoming 2016. Industry Evidence Programme Report: Evidence Based Plans for Offshore Wind²⁷

Figure 9. Cost of Consenting in the UK over time



Source: Renewable UK. 2014. Managing Regulatory and Consenting Costs for Offshore Wind²⁸

²⁷ Figure original taken from Howard. R. 2012. *The Bullet-Proof Consent Application*. Presentation at Renewable UK Offshore Wind Conference in June 2012.

²⁸ Displays indicative cost profiles and costs per MW overtime, estimated by REUK across select UK offshore wind projects. The absolute cost as increased as expected with the increase in size of the projects. However, the trend in cost per MW has not decreased suggesting learnings and experience have not translated into efficiencies.

3.2.5 Lessons learned

The transition to competitive auctions demands greater government site de-risking activities

The reduced certainty of obtaining subsidy contracts through competitive auction systems significantly increases the risk profile for developers to invest in developing new projects. In order to balance the increased allocation and price risk, governments can re-balance the risk profile by undertaking several site development activities up-front, including site investigations, obtaining grid permits, and obtaining full or provisional consent, with data made publically available to prospective developers. The quality of preliminary site surveys and trust in the system are key to reducing developer risk and enabling lower project costs. However, it should be acknowledged that internal capacity building will be necessary to effectively and efficiently deliver de-risked project sites.

Appropriate site selection is critical to mitigating consenting challenges

Most instances where consent has fallen through or been delayed has been due to poor site selection, demonstrating the importance of adequate spatial planning and site identification. For example, in the UK, despite some sites achieving consent relatively quickly, some have experienced setbacks, leading to the cancellation of ~7.6 GW capacity. Similar cancellations have been seen in Germany and the Netherlands.

Consenting regimes should provide a clear framework with defined timelines, coordinated responsibilities, and front-ended consultation

Regardless of the nuances of obtaining consent in different jurisdictions, most critical, particularly where responsibility lies with project developers, is to provide a clear framework with defined timelines and coordinated responsibilities between relevant government agencies. This provides developers with the certainty of obtaining a decision without incurring costly delays. In addition, front ending stakeholder consultation and maintaining this throughout is important to minimise risks of objectives or legal proceedings.

In the UK, the consenting regime in England and Wales has transitioned from Section 36 to the PINS-DCO process, which has a predefined timeline and front-ended activity, including extensive stakeholder consultation. In Scotland, Section 36 is still in force, which has a more flexible approach to timescales by removing the use of predefined deadlines. This increased flexibility has both benefits and drawbacks where by decisions can be made more quickly than the PINS-DCO process however not knowing when a decision will be made can also create increased uncertainty and risk for project developers.

‘One-stop-shop’ entities can streamline the permitting process

The provision of a ‘one stop shop’ for permitting is also beneficial, providing greater clarity for developers and reducing confusion and potential conflicts between different government agencies. Streamlining the permitting and consenting process is beneficial to all stakeholders, both governments and developers.

Greater flexibility in the consenting envelope can future-proof sites for the adoption of innovative, low cost technologies

The degree of flexibility possible in consenting envelopes²⁹ varies by jurisdiction. Some consenting regimes are more rigid with regard to the wind farm design (e.g. Germany), whilst others can accept a wider range of technology options, enabling developers to optimise the wind farm design prior to construction (e.g. UK). Given the long time from consent to final investment decision in many countries and the pace of technology innovation, restricting design envelopes can hinder opportunities to adopt novel cost-cutting technologies. However, this must be balanced with the added complexity and confusion of seeking to obtain consent for a technology envelope that is too wide.

The transition to site-specific tendering also demands greater flexibility. In the Netherlands, all necessary permits are awarded along with the subsidy contract following the auction process, before knowing who will be developing the site. A wide envelope has therefore been adopted to cater for a broad range of technology options from the successful bidder.

In Germany, consenting envelopes are typically more rigid, largely due to the more stringent regulations to adhere to, including noise mitigation, thermal impact of electrical cabling, and more demanding monitoring requirements. For this reason, final consent has been back-ended for the developer to acquire once they have been awarded a contract for subsidy support and grid connection.

Site extensions are a cost-effective means of deploying additional offshore wind capacity

In countries with existing operational wind farms, developing site extensions could offer a lower cost and lower risk alternative to developing new greenfield sites. Extension could be preferable due to (i) existing infrastructure in place (ii) available of site data and (iii) greater certainty over consent. From the grid operator's perspective, adding extra capacity could also be easier to accommodate than connecting new remote sites. Further benefits to developers are that site characteristics and design profiles are already well established and local communities are already familiar with offshore wind, limiting the prospect of local objection. Extra flexibility in the consenting regime can help to facilitate such extensions. However, it should be acknowledged that site extensions may increase wind farm wake effects, which could impact the wind resource for nearby wind farms.

The UK has already pursued this route with a handful of successful extension projects in operation. For example, Kentish Flats, Burbo Bank, and Walney have all been extended to add additional capacity, and several developers are assessing the feasibility to build out sites further, including Vattenfall's Thanet wind farm. In response to increased demand, The Crown Estate is developing a more formal process for acquiring leases for site extensions, which could be particularly attractive in the intensely competitive and capacity-constrained CfD auction process.

²⁹ 'Envelopes' refer to the choice of design of the wind farm, for example choice of foundation, wind turbine size, turbine layout, and cable routing.

The quality of staff within government agencies and statutory consultees and quality of consultation can greatly influence the length and quality of decision making

Criticism has been lodged from developers in the UK that a lack of practical capabilities in statutory consultees can prolong consenting timelines. Cash strapped statutory consultees can struggle to retain sufficient experienced personnel to handle the large number of consenting applications being submitted³⁰. In the UK, developers have sought to overcome this by entering into ‘planning performance agreements’ with the relevant authorities to ensure the competent authority is adequately resourced and expectations are managed for when consultations will be issued.

Scientific research studies can be used to inform and improve consenting processes

Consenting challenges relating to environmental issues typically involve uncertainties over the perceived impact of offshore wind farms on nearby flora and fauna. With over 12 GW of offshore wind installed globally and considerable data captured, there is an opportunity to undertake research studies that can inform and improve our understanding of the true impact. Several research bodies and collaborative joint industry projects have been undertaken, or are currently underway, which are aiming to bridge this gap and reduce the uncertainty and levels of conservatism in the consenting process. However, ensuring that there is a feedback loop between scientific research and relevant consenting authorities should be a priority.

Cumulative environmental impacts are an increasingly important issue for the industry

Increasing importance is being placed on the cumulative environmental impacts of offshore wind farms. As deployment of offshore wind increases, there is now greater risk of cumulative impacts occurring between sites in near proximity. Particularly as project clusters develop to improve economies of scale and optimise transmission assets, the potential for greater impact is a concern for nature conservation bodies. Industry efforts should therefore turn to collecting a robust body of data to better understanding the true impact. In this regard, there is value in closer analysis of post-consent monitoring data from operational wind farms, which can be used to inform future consenting decisions and processes (Box 9).



Box 9: The Crown Estate’s Industry Evidence Programme

In the UK, The Crown Estate, along with academic and industry partners, are attempting to better leverage scientific data through the ‘Industry Evidence Programme’ (IEP). The IEP will bring together the results of all previous EIAs and associated post-consent monitoring from the sector, as well as related research, to produce a sector specific Industry Evidence Base (IEB). Once gathered, the IEB will be widely consulted upon, before being published as a living document, with future projects and monitoring studies adding to and enhancing the evidence base. The outcomes from the research are aiming to determine the most significant issues for wind farm consent, as well as the issues which are not, so that future consenting processes can be streamlined accordingly.

³⁰ RenewableUK. 2014. *Managing Regulatory and Consenting Costs for Offshore Wind*. Available at: <http://ruk.pixl8-hosting.co.uk/en/publications/index.cfm/managing-regulatory-consenting-costs-offshore-wind>

3.3 GRID POLICY

- **Grid connection policies and approaches differ in how risk is borne between the government and developer**
- **Centralised TSO-build approaches can help with strategic coordination of power transmission to ease onshore grid constraints**
- **Decentralised developer-build models can result in lower cost point-to-point transmission assets, but centralised TSO-build models may deliver net lower societal costs if offshore hubs and interconnection can be integrated**
- **TSOs need to be sufficiently capitalised to take on the cost and risk of managing all transmission assets**
- **Suitable liability clauses need to be in place to reduce the risk profile for wind farm developers and transmission operators**
- **Standardisation and innovation can deliver considerable cost reduction**

Grid connection is fundamental to the operation of an offshore wind farm. Due to long lead times and high costs of building transmission assets, coordinated forward planning is key to ensuring timely connection and minimising costs to both developers and consumers. A coordinated approach to grid connection is increasingly important as the individual and cumulative scale of offshore wind farms increases. This has led to significant innovation in the development of new technologies and fundamental switches in policy regimes in order to mitigate risks and minimise costs for consumers.

Grid connection typically encompasses an offshore converter station, transmission lines (export cables) connecting the offshore substation to an onshore substation, and onshore grid transmission networks. To date, radial offshore wind farms have been connected individually back to shore, typically through high voltage AC transmission, where TSOs are generally obliged to provide access to the onshore grid. However, high voltage DC transmission has also been implemented in some countries, particularly for far-shore projects where multiple wind farms connect into a single converter station. Offshore wind also brings the potential for interconnection between two or more countries. Although this has yet to be demonstrated, Kriegers Flak offshore wind farm in Denmark has recently been allocated subsidy support, along with EU funding, to build the world's first offshore wind farm connected to an interconnector between Denmark and Germany.

Transmission assets are expensive and have very long lead times, hence the design, installation, and operation are crucial elements for all stakeholders. Not least for the generator, whose revenue streams are dependent on the successful operation of the grid. Long lead times can often force developers to place orders with equipment manufacturers before designs are finalised. This pressure is further amplified due to time restrictions to achieve financial close in order to retain subsidies. For example, in the UK strict timelines exist once the subsidy has been awarded to ensure sites and subsidies are not held indefinitely. The responsibility for designing, building, financing, and operating connections differs across countries and is explored in more detail below.

Figure 10. Offshore wind electrical infrastructure



3.3.1 Policy tools

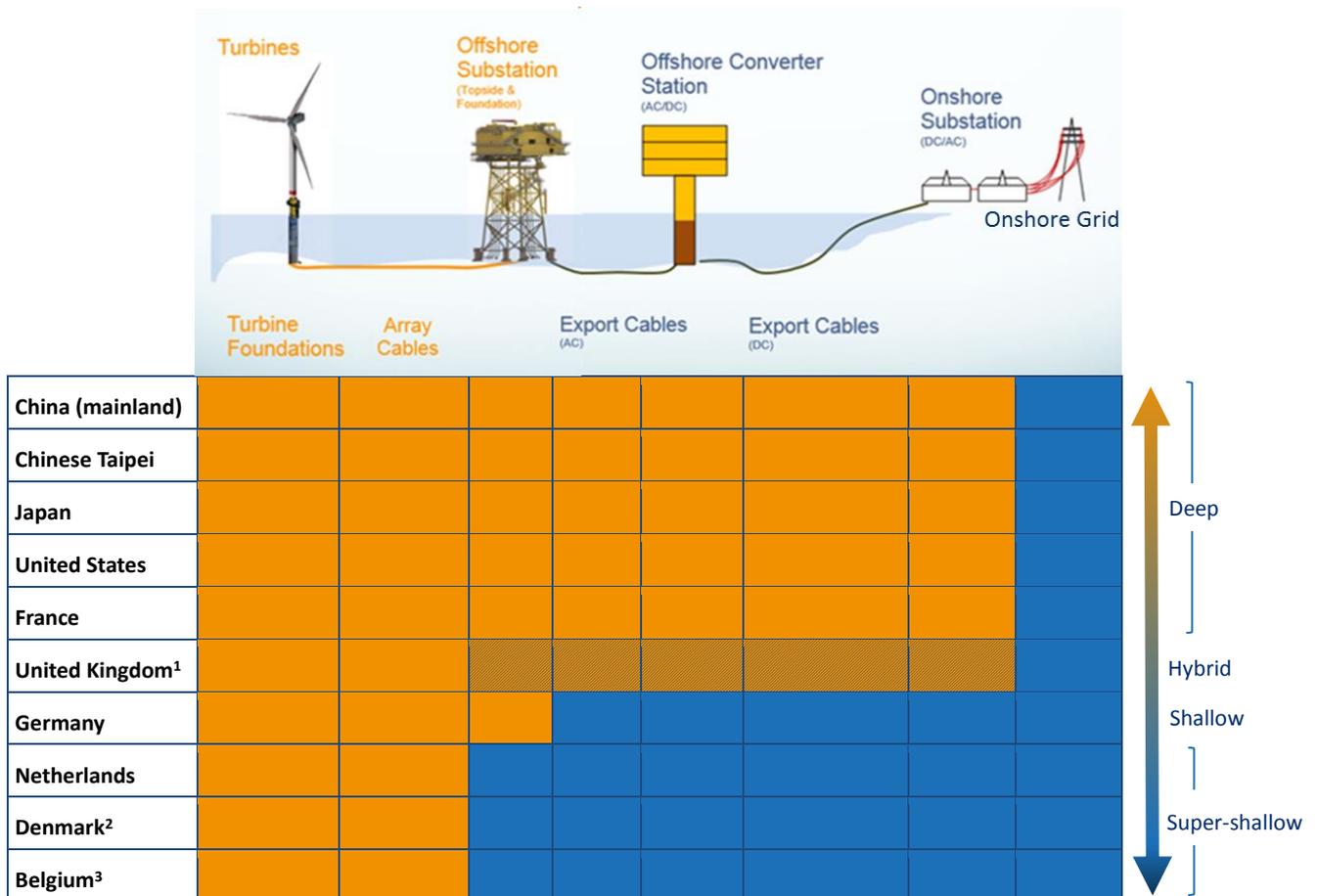
Regulating who takes responsibility

Grid connection policy and approach across front runner countries differs in how risk is shared between the TSO, developer, and third parties. This is characterised by the depth of charging for a wind farm developer.

- **Deep charging model:** Developer is responsible for constructing and operating all offshore transmission assets, often including onshore reinforcements (i.e. onshore substation and cable routing). *Example: United States.*
- **Shallow charging model:** Developer is responsible for intra-array cabling and offshore substation. TSO provides transmission infrastructure to export electricity back to shore. *Example: Germany.*
- **Super-shallow charging model:** Developer is responsible for intra-array cabling and connection into a substation only. TSO provides substation, export cabling, and onshore reinforcements. *Example: Denmark.*
- **Hybrid deep-shallow model:** Variants on the models above. This can entail a developer constructing the offshore assets but transferring ownership and operation to a TSO or third party. *Example: United Kingdom.*

The efficacy and trade-offs of each approach is explored below, but it should be noted that this is heavily dependent on local context, including available capacity in existing transmission networks, locations of offshore wind farms, and institutional structures.

Figure 11. Overview of responsibility for construction and operation of offshore transmission assets (orange: developer responsibility; blue: TSO/third party responsibility)



¹ Developer builds assets, sells to OFTO (who operate the asset), and developer pays fee for usage. OFTO-build model, whereby a third party constructs the offshore assets, is also available but has yet to be implemented.

² Official offshore tender – TSO responsibility for grid connection; Open door or Nearshore – developer responsibility.

³ Developer can choose to build grid connection and receive higher FIT (€150/MWh vs. €138/MWh).

Denmark were an early adopter of a centralised super-shallow model, whereby the TSO (Energinet.dk) provides the necessary offshore transmission assets. The Netherlands is also currently transitioning to a super-shallow model in which TenneT, the state owned TSO, is rolling out a series of grid expansion schemes in line with the offshore development plan. As well as construction and operation of assets, this centralised approach entails the TSO taking responsibility for a greater share of the preliminary works, including grid permitting.

The far-shore location of offshore wind farms in the German North Sea has necessitated the use of high voltage DC transmission, under a shallow model in which the TSO, TenneT, constructs the DC transmission assets and provides an AC connection point for nearby wind farms. Developers are responsible for constructing the AC substation and intra-array cabling. In the Baltic Sea, wind farms are connected by AC transmission, administered by the TSO, 50Hertz.

The UK, favouring increased market competition, has adopted a more decentralised hybrid model that includes third party owners, known as Offshore Transmission Operators (OFTOs). Construction of transmission assets is typically undertaken by the developer, who are mandated to sell the assets on to an independent offshore transmission operator (the OFTO). OFTOs are also eligible to build the assets, but despite strong backing by the UK regulator, Ofgem, and the necessary legal provisions in place, no developers have elected to undertake an OFTO-build approach. This is largely due to concerns over an OFTO's ability to deliver on time and on budget, as well as take on the high risks and costs involved, which are better placed with utility developers.

Most emerging markets, where deployment has been limited to date, appear to favour a deep charging model where project developers are required to construct and operate transmission assets. As these markets mature and deployment volumes increase, countries may consider transitioning to shallow charging models. The relative strengths of the different approaches, as well as challenges to implementation, are discussed further in the proceeding sections.

Developer vs TSO responsibility

From a developer's perspective, the 'developer build' deep-charging model provides greater control and certainty, lowering the risk of connection delays. Greater control over the construction and operation of their assets enables developers to strategically steer decisions over design, innovation, and construction and operation strategies. However, responsibility for the construction and operation of offshore transmission assets does expand the scope of activities and level of financing required by the developer, which can impact on the cost of capital for project financed wind farms.

While a developer-build model arguably results in a lower cost point-to-point transmission asset, in some countries there are benefits from greater central coordination of onshore and offshore grid networks, which can lower costs and risks from a systems perspective. This is particularly relevant in countries with onshore grid constraints (e.g. Germany; see Box 10). Phased deployment with a clearly defined schedule can also help to mitigate potential supply chain bottlenecks and provide greater visibility for the TSO to coordinate necessary onshore upgrades. This latter approach has been adopted by the Netherlands.

Table 5 provides a comparison of the different trade-offs across the three models from the developer and government's perspective. It should be noted that the approach to offshore transmission assets is very much contextualised to the country specifics, including the flexibility of the transmission system and the institutional structure of system operators.


Box 10: Grid transmission assets in Germany

Onshore grid constraints are a major challenge for the German energy sector, with constraints on transmission capacity from high load production in the North to high demand centres in the South. The bottlenecks and delays in reinforcing the onshore transmission network is part of the reason why offshore wind deployment targets have been scaled back in recent years. Strategically coordinated grid expansion plans have therefore been introduced to inform the location of future offshore wind farms, which enables more proactive, rather than reactive, planning. Placing control over grid assets with the TSOs, TenneT (North Sea) and 50Hertz (Baltic Sea), helps to implement this more coordinated approach. For example, upcoming auction rounds will initially be limited to wind farms in the North Sea only, due to grid constraints affecting projects in the Baltic Sea.

Another driver for TSO control over offshore grid assets is the far-shore location of several North Sea offshore wind farms, which need to be connected by high voltage DC transmission lines and converter stations. These DC substations act as hubs for nearby wind farms to connect into. Given the complexity of multiple party ownership of such high cost and important assets, TSO ownership mitigates the risk of conflicts and complex charging methods that would be required from developer ownership.



Source: TenneT

Table 5. Comparison of the different trade-offs across the three models from the developers and governments perspective

	Government Perspective	Developer Perspective
Developer Build/Operation <i>'Deep model'</i>	<ul style="list-style-type: none"> + Lower cost and risk to government + Optimised point-to-point asset minimises costs to consumers + Increased competition stimulates cost reduction - Less control over strategic coordination of grid assets - Challenging to introduce converter platform hubs or interconnection 	<ul style="list-style-type: none"> + Greater control over the design and construction of the transmission assets + Reduces the risk of unforeseen or uncontrollable connection delays and lost revenue + Ability to introduce technology innovation to optimise assets and gain competitive advantage - Higher cost and added construction risk for developer - May need to take on additional debt to finance construction
TSO Build / Operation <i>'Shallow/super-shallow model'</i>	<ul style="list-style-type: none"> + Emphasis on security of supply, rather than cost + Ability to strategically build offshore hubs and coordinate onshore upgrades + Ability to share assets between multiple wind farms + Ability to standardise substation designs for economies of scale savings - Cost to consumers may be higher if not optimised - Limited competition can result in higher costs 	<ul style="list-style-type: none"> + Fewer assets to manage – lower risk provided compensation is in place to mitigate risk of downtime + Reduced developer investment, which can lead to lower cost of capital - Higher risk of delays or design inefficiencies from TSO – need adequate compensation in place to mitigate - Risk of low incentives for TSO to maintain to a high standard – downtime causes lost revenue - Less control over asset design

	Government Perspective	Developer Perspective
	<ul style="list-style-type: none"> - High cost and risk sitting with TSO to build and manage all offshore assets – TSO needs to be suitably capitalised to take on risk - Public ownership exposes consumers to high risk if TSO is liable to pay compensation 	
Third Party Build/Operation (e.g. OFTO) <i>'Hybrid model'</i>	<ul style="list-style-type: none"> + Meets objective to unbundle the energy sector + Greater competition for asset operation can lower costs for consumers + Greater transparency of costs to consumers - Third party may not be capitalised in such a way to manage risks of expensive assets 	<ul style="list-style-type: none"> + Fewer assets to manage – lower risk provided compensation is in place to mitigate risk of downtime + Reduced developer investment, which can lead to lower cost of capital - Less control over asset maintenance – risk of revenue losses - Challenging interface between wind farm operator, third party, and onshore TSO - Stringent availability targets and meaningful penalties are required to ensure efficient operation and maintenance of transmission assets

Grid planning

A centralised approach to grid planning assigns the lead authority and its sister government agencies with the responsibility to plan onshore and offshore transmission upgrades in an effective manner. From a societal perspective, central planning of offshore wind development can ensure alignment with necessary grid upgrades and mitigate the risk of connection delays.

In contrast, a decentralised model can make it difficult for the TSO to plan upgrades effectively. With limited visibility on the sites that will secure subsidy contracts, TSOs may struggle to plan where and to what capacity upgrades will be required. In addition, strict timescales post-auction can add to these challenges, leaving little lead time to implement necessary grid reinforcements. This is particularly relevant as wind farms reach GW scale, where onshore networks are impacted more significantly.

However, the preferred option is heavily dependent on local context. If the onshore grid network has sufficient capacity and flexibility to accept additional GW scale capacity with shorter lead times, a developer controlled model may result in lower cost point-to-point transmission assets. Conversely, if the onshore grid is more heavily constrained, a centralised approach can facilitate tighter control over the scale and timing of new capacity. Centralised approaches can also enable multiple projects to share electrical infrastructure, although the merits of this approach diminish as individual project size increases, since each project is likely to require its own substation.

**Box 11: Planning for upgrades in the UK**

The UK's electricity grid infrastructure is old and whilst it has been upgraded over time and reliably delivers power, it experiences north-south capacity constraints and limitations on where new high-voltage current can be interconnected. With the build out of several large power generation sites at Round 3 development zones, such as East Anglia, Hornsea, Moray Firth, and Dogger Bank, onshore upgrades are likely to be required.

To date, the UK has followed an 'invest then connect' approach, where developers apply for connection to the transmission network and the transmission licensee (National Grid, SSE, or Scottish Power) makes an assessment of the transmission network reinforcement required to connect the new generation unit(s). The developer must then wait for these grid reinforcements to be completed by the TSO before it can connect to the network. This delay can be of an indeterminate period, depending on the rapidity of the TSO and if and how quickly planning approval can be secured.

Grid permitting

Grid permits are required in order to construct and operate grids. This typically involves filing for and acquiring permits, examination of options, and technical studies. In a centralised model, permits and power purchase agreements are secured by the government in advance of subsidy contract award. This reduces risk for the developer and shifts the cost of development work on to the government. In a decentralised model, there is a higher risk that the developer does not obtain the permits required to secure the connection. In the UK, this is typically mitigated to an extent by the need to secure a connection offer before being eligible to enter auction rounds. However, deep-charging models can increase the prospect of litigation and or opposition from statutory consultees which could result in the cable route being re-directed (i.e. to avoid environmental impacts or simply to connect to the best onshore point connection) and result in higher costs for wind farm developers. Securing power purchase agreements is also a key challenge in the United States, where several projects have struggled to secure offtake agreements with state utilities (see Box 12).

**Box 12: Power purchase agreements in the United States**

The ability to secure a power purchase agreement (PPA) with utilities has been a major obstacle to offshore wind development in the United States. A PPA is an agreement between the wind farm generator and utility to purchase the electricity at an agreed price. With the US market currently dominated by small independent power producers (IPPs) and foreign developers (i.e. lack of active US utilities developing offshore wind farms), PPAs are essential to enabling projects to proceed.

However, the high relative cost of offshore wind in the United States, particularly for early projects, and a lack of regulation to mandate the purchase of renewable or offshore wind energy, has left several project developers without a route to market. For example, two Department of Energy (DOE) funded demonstration projects – the 30 MW WindFloat pilot project off the coast of Oregon and Fishermen's Energy's 24 MW project in New Jersey – have stalled and lost funding support having missed deadlines to secure PPAs. Several other projects are still in negotiations to obtain the necessary PPAs to proceed with construction, but have suffered from delays and greater uncertainty of securing an off-take agreement.

This barrier is being mitigated in some states by the introduction of legislation which mandates utilities to procure electricity from offshore wind. Massachusetts, for example, have enacted an energy bill which includes a requirement for utilities to enter into long-term contracts for 1.6 GW of offshore wind by 2027.

Transmission asset construction

The timing of grid construction is critical to ensure that there is fully operational grid infrastructure in place when the offshore wind turbines have been commissioned and are ready for operation. Building out offshore transmission assets and onshore grid reinforcements is a lengthy and costly process, which often precludes anticipatory works from being undertaken. This creates a short lead time to construct the transmission assets, leading to the risk of connection delays.

In a deep-charging model, the developer has greater control of when to start construction and can ensure that this fits within the development plan. In addition, developers can seek to leverage vessels already under contract to support the process and ensure that delivery is coordinated with the rest of the wind farm construction schedule.

In a centralised shallow-charging model, where the TSO takes the lead, there is higher risk to the developer that the grid assets are not built on time, leading to lost revenue, as experienced in Germany (see Box 13). However, centralised planning can also be designed to reduce the risk of supply chain bottlenecks and mitigate risks for wind farm developers. Stable and phased deployment of offshore wind with clearly defined timescales can allow TSOs to plan delivery schedules with longer lead times to avoid potential bottlenecks and support standardisation in the construction of large converter platforms. Suitable compensation is also a key requirement to alleviate risk in the event of delays.

The ability to plan and coordinate ahead of time contrasts to the decentralised approach where developers and TSOs must be more reactive to auction wins, creating a short turnaround from contract award to meeting delivery milestones. DONG Energy's model for standardised substation units mitigates this risk to some extent, but only applies to developers with a sufficiently large portfolio who can spread risks and achieve economies of scale across a number of projects.

Capitalisation of asset owners

A key requirement for a centralised grid connection model is that the TSO is sufficiently capitalised to take on the high cost and risk of delivering transmission assets to all of a country's wind farms. This has proved particularly challenging in Germany, where grid delays were partly attributed to the high cost and limited lead time for TenneT to deliver the necessary transmission networks. Public ownership of TSOs can help to mitigate this risk and there may need to be a mechanism for TSOs to raise the necessary capital. For example, in the Netherlands the government have a majority stake in TenneT, who have also been able to raise capital through green bonds, co-investment with equity partners, and debt finance. Coordinating and scheduling a phased delivery of assets can ease these challenges by facilitating a more even spend profile for TSOs.



Box 13: Grid connection delays in Germany

Offshore wind development in Germany has suffered considerable setbacks as a result of grid connection delays in the North Sea.



Cause: Having announced a highly ambitious schedule for offshore wind build out, the compressed timeline and scale of build proved too costly and risky for TenneT to take on. The spike in project development left TenneT needing to supply 5 HVDC units in a single year, with limited lead time to plan accordingly. The bespoke custom build required for each substation and added complexity of new HVDC technology also contributed to the additional time required to deliver the assets.

Most critical was the financial burden this imposed on TenneT, who were not suitably capitalised to take on the high cost and risk of the proposed construction pipeline, leaving a €5bn hole, almost half of the total finance required. As a private company, TenneT were unwilling to take on significant levels of debt finance and had to sell stakes to external investors (e.g. Mitsubishi) and issue green bonds in order to free up the necessary capital, with the added time leading to considerable delays.

Impact: The impact of project delays has been extremely damaging to industry confidence and suppliers, leading to national targets being scaled back. Lower deployment levels have limited opportunities for suppliers to secure market share, losing early mover advantage that could have been gained in the European market. There were also financial losses incurred by suppliers who had invested ahead of time in anticipation of orders, hitting revenue streams, particularly in high cost infrastructure, such as installation vessels.

Delays have also been damaging to project developers, who have incurred higher development expenditure as a result of the delays. Some developers have even incurred costs of having to use diesel generators to keep turbines operating in necessary working conditions. Later commissioning dates also increase the risk of projects missing out on preferential remuneration tariffs, with some projects slipping into competitive auctions where margins will be far tighter.

Mitigation: The delays incurred have triggered the introduction of new regulation to limit the risk exposure for grid operators. This includes the adoption of an offshore grid development plan to coordinate transmission upgrades to a more manageable schedule and the introduction of liability clauses that limit the risk exposure of the responsible TSO. TSOs are now able to postpone grid connection dates up to 30 months prior to completion date, increasing risk of delays for project developers. However, any changes made within this 30 month window will result in compensation to wind farm owners. TSOs are also liable to penalties of up to €110m per year for delays to connection timelines.



Developers are entitled to compensation of 90% of their lost revenues from any delays to connection or downtime suffered during operation. Alternatively, developers may accept an extension to the feed-in tariff. It should be noted that developers are only entitled to compensation when continuous downtime exceeds 24 hours, which can increase developer risk and leave no compensation for intermittent downtime over shorter timeframes.

Learnings: The challenges encountered in Germany have served as important lessons for the industry, which have been taken on board by RVO and TenneT in their approach to grid connection in the Netherlands. Long-term planning with capped tendering rounds will result in phased build out at predefined intervals, with standardised substation designs rolled out across all 5 wind farm zones to aid more efficient production lines. Visibility and long lead times also mitigates the risk of supply chain bottlenecks. Moreover, liability clauses have been adopted that will provide compensation to wind farm operators in the case of any delays or downtime

Grid operation

The operation of the transmission assets is important to ensure (i) a secure supply of electricity is available for the TSO to call upon to meet energy demand and (ii) secure revenue streams for the owner/operator. A centralised model allows the developer to run a leaner operation which focusses on operating a smaller number of assets. Where transmission assets are owned and operated by third parties or TSOs, availability targets are adopted to incentivise efficient operation to limit the risk of downtime for developers. In the UK, Ofgem has set an availability target of 98% for OFTOs to achieve³¹.

However, appropriate penalties need to be in place to ensure that these availability targets are met. This is a critical aspect of grid policy which must balance considerable financial risk between developers, third parties, and consumers. Full compensation for lost downtime is preferable for developers but can equate to high cost to asset owners, which may be beyond the financial capabilities of third parties or could result in high costs to consumers. Proportional compensation can mitigate this risk for asset owners but places considerably higher risk on developers, who are more exposed to financial losses from periods of downtime. Downtime may also have to exceed a prescribed period of time to warrant compensation. For example, in Germany, developers are only compensated for continuous downtime exceeding 24 hours; although 90% of lost generation is covered after this point.

Standardisation versus innovation

A centralised model provides the ability to standardise cables and substation design over multiple sites, allowing for serial production that unlocks economies of scale. In contrast, a decentralised model provides opportunity for greater developer control to produce lower cost point-to-point assets. For developers with a large project portfolio, standardisation might also be possible if a developer's portfolio is large enough. For example, DONG Energy have developed a standardised converter platform design which can be serially fabricated and deployed in multiple projects across Europe.

Commonly, standardisation and innovation are not viewed as wholly compatible and risk stifling the development of one another. However, if designed appropriately, standardisation and innovation can both be incorporated into transmission asset design. Both the examples of DONG Energy and TenneT NL (see Box 14) demonstrate how technology innovation can be incorporated in standardised designs which are future proofed to adapt to emerging technology trends.

³¹ OFGEM. 2014. *Offshore Transmission OFTO Revenue Report*. Available at: <https://www.ofgem.gov.uk/ofgem-publications/91890/es902offshoreoftorevenuereportweb.pdf>



Box 14: Netherlands – TenneT approach to offshore substations

The transition to a centralised development model in the Netherlands (part of the national roadmap for offshore wind) has shifted the responsibility for constructing and operating offshore transmission assets to state-owned TSO TenneT. The roadmap for offshore wind development consists of a 5 year phased deployment of 700 MW per year. The equal size of wind farm capacity has partly been enforced to enable TenneT to standardise the design of the offshore transformer, unlocking economies of scale to deliver cost reduction. Five identical substations have been designed following extensive consultation with stakeholders and adopting learning from their German counterparts, where bespoke substation designs contributed to higher costs and construction delays.

Engagement with industry suggested that 700 MW was an optimal size for the transformer, big enough to cater for large scale projects but of sufficient size to align with supply chain and infrastructure capabilities for fabrication and installation. The designs have been future proofed for near term technology innovation, with the ability to accept 66kV inter-array layouts. The centrally coordinated approach has also allowed for optimal cable siting, whereby 220kV export cables will come to shore only 1km away from the existing 380 kV onshore substation. For each 350 MW wind farm, 30 MW of overplanting has been allocated to stay outside of the compensation scheme.

The visibility and annual phasing of delivery will allow both TenneT and equipment suppliers to plan accordingly, both in terms of managing production lines and undertaking necessary onshore grid reinforcements. The first substation is expected to be tendered in 2017 for operation in 2019, with annual additions for the following 5 year period. This long lead time will mitigate potential supply chain bottlenecks, resulting in lower fabrication costs. Internal cost analysis from TenneT suggests that this approach will deliver a net lower societal cost relative to a developer build model (RVO Development Framework for Offshore Wind Energy, 2016).



Tender (Year)	MW	Location	Operational connection
2016	700	Borssele Alpha	2019
2016	700	Borssele Bèta	2020
2017	700	Hollandse kust: Zuid-Holland	2021
2018	700	Hollandse kust: Noord-Holland	2022
2019	700	Holland kust: Noord-Holland	2023

Interconnection

Interconnection between countries is priority in the EU with the increasing push to integrate offshore renewables³². The EU has a target of 10% of interconnection capacity between neighbouring countries of their installed electricity production capacity by 2020, with an increase to 15% by 2030 having been proposed³³. Benefits of increased interconnection include: more reliable system lowering the risks of blackouts; reduced need to build new power stations; lower societal energy costs; the ability to better manage intermittent renewables; and in some cases allows for the development of more renewable energy sources, which can support decarbonisation efforts.

³² See the EU E-Highways 2050 and the NSCOGI (North Sea Countries Offshore Grid Initiative) for more information.

³³ European Commission. 2015. Connecting power markets to deliver security of supply, market integration and the large-scale uptake of renewables. Available at: http://europa.eu/rapid/press-release_MEMO-15-4486_en.htm

Where centres of activity are focalised, there are opportunities to interconnect offshore wind farms with each other and to connect to established or newly planned interconnectors (see Box 15). A centralised approach makes it easier for international parties to collaborate and to integrate interconnection, namely due to reduction in parties involved. For example, TenneT’s presence in both the Netherlands and Germany could streamline and simplify commercial arrangements, whereas the OFTO regime in the UK could make interconnectivity more complex in terms of the number of parties and interfaces involved.

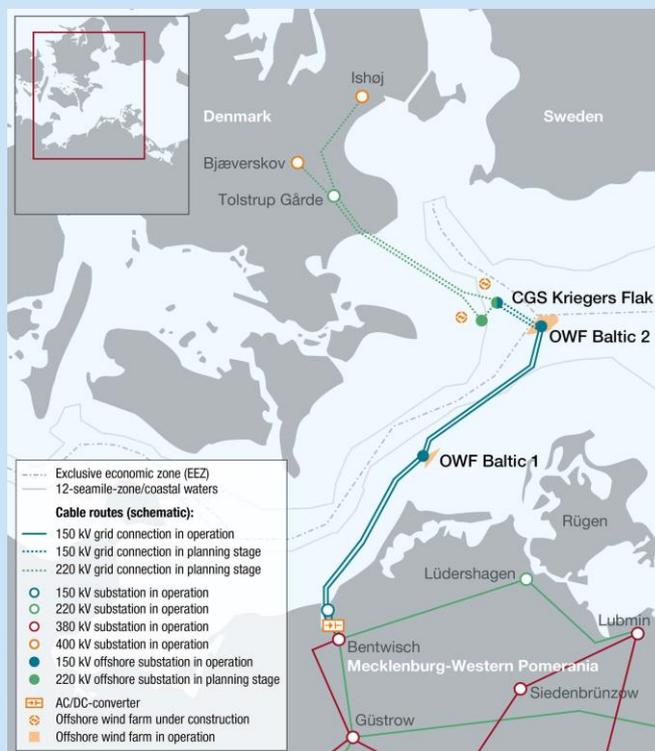


Box 15: Kriegers Flak Combined Grid Solution

The Danish and German TSO’s responsible for the Baltic Sea, Energinet.dk and 50 Hertz, plan to deploy the world’s first integrated interconnection with an offshore wind farm, known as the ‘*Kriegers Flak- Combined Grid Solution*’. The CGS will connect eastern Denmark with the German state of Mecklenburg Western Pomerania with a planned transfer capacity of 400 MW. The aim of the project is threefold: firstly, to increase the supply of renewable energy to EU consumers; secondly, to strengthen regional energy markets; and lastly, to increase security of supply.

Vattenfall will develop the 600 MW Kriegers Flak project, having been awarded a subsidy contract of just €49.9/MWh from the tender auction, a new landmark low for the industry. The interconnection link will pass through two German wind farms, EnBW’s 288 MW Baltic 2 wind farms, which lies 30km adjacent to Kriegers Flak. Frequency transformation will be required due to Germany and Eastern Denmark operating on two different synchronous areas. This will be addressed through two voltage source converters (VSC) and offshore transformers. Two submarine cables will connect the wind farms with the onshore network.

The interconnection has been awarded a PCI (Project of Common Interest) status by the European Commission and will received up to €150m of financial support from the European Energy Programme for Recovery. It is expected to receive a permit in 2017, with construction, installation and testing to take place between January 2017 and December 2018.



Source: Wind Power Offshore, 50Hertz, Renewables-Grid.EU

3.3.2 Lessons learned

Grid connection policies and approaches differ in how risk is borne between the government and developer

Different policy approaches have emerged to managing the planning, design, construction and operation of transmission assets across front runner countries. Three key approaches exist: a decentralised model where the developer is heavily involved; a centralised model where the government takes the lead; and a third party ownership model where a third party is appointed to manage transmission lines. Stakeholder consultation suggests each approach as its advantages and trade-offs, with the most appropriate approach dependent on local context, including the degree of onshore constraints and ability of the grid operator to take on the cost and risk of multiple transmission assets. There are strong benefits to unbundling grid ownership, competitive tendering, and having a single system operator for both the onshore and offshore grid infrastructure, but finding the correct balance is highly dependent on local context and the prevailing market conditions and regulatory regime.

Decentralised developer-build models can result in lower cost point-to-point assets, but centralised TSO-build models can ease onshore grid constraints and may deliver net lower societal costs

Recent industry trends have seen a transition from decentralised models (government-build) towards more centralised models (government/TSO build). While developer-build models are likely to result in lower cost point-to-point assets, given the increased incentives to deliver cost reduction and optimise asset design, a centrally coordinated and managed approach can be beneficial in enabling strategic coordination of transmission upgrades. This is particularly beneficial in countries where onshore grid constraints are a major issue and/or where far shore offshore projects can benefit from shared electrical infrastructure (e.g. Germany). Greater coordination and sharing of assets, as well as greater interconnection, could lead to lower societal costs. However, a centralised approach will require TSOs to be suitably capitalised to take on the high cost and risk of building extensive offshore transmission assets.

Greater coordination and strategic planning is expected to be required as offshore wind deployment increases

The need for greater coordination between offshore and onshore transmission networks is particularly important as individual project and cumulative capacity of offshore wind increases. Whilst grid networks across Europe have generally been able to accommodate the current levels of offshore wind to date, future development plans, which aim for GW scale wind farms, could pose significant challenges to onshore grid operators. The challenge of connection such large scale capacity is often under-estimated by policy makers, as these entail high costs, long lead times, and lengthy stakeholder discussions, as well as public consultations. The example of the Netherlands demonstrates that a clear and stage-gated approach to developing offshore wind can provide the TSO with the visibility required to mobilise resources to build out and reinforce the grid. There is therefore the need to go beyond dialogue and stimulate collaboration between developers, offshore grid operators, transmission system operators, and regulators to define a harmonised vision, approach and support schemes.

Strong incentives and penalties are required to ensure transmission availability is maintained

If the responsibility for the transmission assets is instilled to a TSO or third party, it is important to ensure that adequate policies are put in place to ensure that availability targets are met. Stakeholder engagement suggests that many developers prefer to maintain control of grid assets, due to the added risks of connection delays if responsibility is held by a TSO or third party. However, if a centralised approach is adopted, it is important to ensure that suitable provisions are in place to manage liability and provide compensation to wind farm developers if delays are incurred, as well as downtime during operation.

Standardisation and innovation can both deliver considerable cost savings

The industry has proven it can innovate and reduce costs with the provision of large orders. Both the centralised and decentralised models can support both innovation and standardisation. While the centralised approach is more aligned to standardisation, industry engagement on prevailing technology trends can ensure that designs are future proofed to incorporate novel innovations. The developer-led decentralised approach arguably increases drivers for design optimisation and innovation to deliver lower costs to wind farm operators, while a degree of standardisation is still possible, particularly for developers with larger project portfolios. However, ultimately, in order for this to be possible long term market visibility is required, backed up by transparent and stable policies.

Electricity markets need to be designed to reward the system benefits of offshore wind

Offshore wind is a scalable and flexible energy technology with high load factors which exceed those of other renewable energy sources, such as onshore wind and solar PV. As a flexible electricity generator, offshore wind can also be an effective tool for load balancing in an electricity system with an increasing share of decentralised and intermittent renewable energy, thereby reducing the need for reserve generation capacity. These system benefits can support national goals on energy security and reducing costs to consumers, but are not rewarded under the current design of electricity markets, which typically prioritise energy technologies according to their levelised cost of energy (LCOE). To fully account for and reap the benefits of offshore wind development, governments should look beyond LCOE to also consider wider benefits for the electricity system, as well as alignment with domestic industrial policy. Adequate incentives will need to be embedded within the electricity system to reward generators for the added flexibility in meeting load balancing requirements.

3.4 INCENTIVE MECHANISMS

- **Various incentive mechanism design options are available to policy makers, which balance risk between government and developers**
- **Governments must balance low costs with the risk of non-delivery**
- **Beyond mechanism design, the most important factor is providing clarity, visibility, and stability**
- **Transitions from fixed-remuneration systems to competitive auctions can introduce higher allocation and price risk and need to be managed carefully**
- **Emerging markets should carefully consider when to adopt competitive auction systems**
- **Ability to adopt competitive approach depends on domestic capabilities**
- **Competitive auctions should be designed to deter speculative bids and penalise non-delivery**

Although rapidly maturing, compared to other electricity generation sources (such as coal, gas, onshore wind, solar PV) offshore wind is a relatively nascent energy technology that requires public funding support to stimulate deployment. A range of incentive mechanisms have been introduced in different countries and at different stages of market maturity to attract the inward investment necessary to initially demonstrate the technology and progressively increase deployment levels, reaching the volumes of scale needed to drive down costs. The recent cost reduction observed in industry is largely the outcome of stable policy frameworks in several markets which have adopted attractive incentive mechanisms.

The most effective incentive mechanisms in catalysing deployment have been those that have reduced the level of risk for developers and investors, providing greater certainty that they will be able to recover costs. However, incentive mechanisms must strike a balance between offering attractive profit margins to risk-averse investors whilst avoiding unreasonable costs for the end-user. This can be achieved by balancing a number of design considerations, as detailed further below.

As industries have matured, incentive mechanisms in offshore wind have evolved to transfer risk from government to private investors, reducing the level of public expenditure and creating more competitive systems that minimise price risk for consumers. This shift to competitive auction systems has been successful in delivering substantial cost reduction, as evident in a number of recent contract awards across Europe. However, emerging markets should use caution to move to competitive auctions prematurely, and must ensure that support schemes are designed appropriately to limit risk exposure for government and industry players.

3.4.1 Evolution with market maturity

Incentive mechanisms have evolved over time in response to growing technology and market maturity. Typically, governments will take on greater risk in early development stages with grant and fixed remuneration support offering stability and lower financial risk for investors. As markets mature, fixed remuneration levels gradually fall before eventually moving to competitive auction-based systems.

Table 6. Incentive mechanism requirements by market and technology maturity

Demonstration projects	Early commercial projects	Large-scale commercial projects
Maturity		
Capital grants	Fixed off-take contracts	Competitive auctions
<ul style="list-style-type: none"> • Supports early projects where costs are uncertain due to lack of experience • E.g. UK Offshore Wind Capital Grants Scheme 	<ul style="list-style-type: none"> • Market-based mechanism • Provides commercial returns for developers, based on energy generation • E.g. Feed-in premium; UK ROCs 	<ul style="list-style-type: none"> • Increased competition encourages cost reduction • Auction budgets can help to control government spend • E.g. UK Contracts for Difference

Source: Carbon Trust Analysis

While this pathway has been common in some early mover markets, such as the UK (see Box 16), it is unlikely that this same trend will be followed in new emerging markets, particularly those in the EU where state aid and electricity market rules are prompting a shift away from fixed remuneration levels. In the UK, a capital grants scheme was adopted to guard against high uncertainty and risk in deploying a novel technology in challenging offshore environments. Higher up-front funding could cover high capital expenditure and negate the need for unfavourable debt financing. However, the greater track record and experience of deploying over 12 GW of offshore wind internationally means that the entry point for new markets is being brought forward. This is already evident in many emerging markets, where fixed remuneration systems are common and some are even moving directly to competitive auctions. Grant funding still has a role to play, but this is typically reserved for higher risk technology demonstrations.



Box 16: United Kingdom incentive mechanism evolution

The UK has used three major mechanisms to support offshore wind, and has deployed them at different times to achieve different results. The incentives that have been used are:

- **Offshore Wind Capital Grants Scheme (2002-2012):** The Offshore Wind Capital Grants Scheme was designed to stimulate an initial pipeline of project proposals that would be used by the government to gather data on sites and project costs, and to inform the design of future incentive cost structures and cost levels. High up-front funding support reduced risk for developers of these early and smaller scale projects, typically <100 MW in capacity. The Capital Grants Scheme funded just over 1 GW of offshore wind in the UK, before transitioning to the RO regime.
- **Renewables Obligation (2002-2017):** The Renewables Obligation (RO) pushed electricity suppliers to source low carbon electricity and also provided financial incentives for different types of renewable energy, including offshore wind. Renewable Obligation Certificates (ROCs), dictated by auction, were issued to developers in addition to wholesale power price. Low allocation risk and a 20 year support structure helped to incentivise considerable activity in the UK, supporting ~5.5 GW of deployment.
- **Contracts for Difference (2017-Present):** New mechanism following Electricity Market Reform (EMR) in the UK to provide greater certainty on the expected revenue generated by renewable projects. Contracts for Difference provide a fixed level of support over a 15 year period, giving project developers a more predictable level of financial support than the RO and therefore greater confidence in the economic viability of their projects. A shorter 15 year support period is also more favourable, providing more up-front remuneration to pay off debt financing on large scale commercial projects. Increased competition has been successful in driving down costs, but this change in mechanism design has created uncertainty through higher allocation and price risk for developers.

Together, these incentives have been designed to carve a path for offshore wind from a position of weak data, high costs, and high risks, to one that enjoys richer data, longer term certainty, lower risk, and more investible offshore wind development opportunities.

3.4.2 Policy tools

Remuneration system design

A multitude of different remuneration systems have been adopted to stimulate renewable energy markets worldwide across a number of technologies, including offshore wind. The most common form of remuneration is through feed-in tariffs or premiums, which provide subsidy payments per unit of electricity generated. As of 2015, 110 jurisdictions had live feed-in tariffs policies in place, making them the most widely used policy mechanism to incentivise clean energy production. As renewable technologies mature and transition towards competitive auctions, sliding feed-in premiums are increasingly seen as the preferred incentive mechanism for governments. In addition, other fiscal policies, including grants, loans and tax incentives remain important tools.

Offshore wind has been supported by a range of incentive schemes. The level of support and design of the incentive scheme differs per country, equating to different levels of risk and cost for generators, investors, and consumers. Governments have adopted different approaches to reduce the risk profile for investors, creating the necessary incentives to drive deployment and cost reduction to achieve national energy goals. Lower risk for investors can result in a lower cost of capital, resulting in a lower cost of energy and ultimately lower cost to consumers, at least on a per MWh basis. However, governments must balance this with the total level of public expenditure available and maximising deployed capacity over a given funding period.

A range of levers and options available to policymakers in designing suitable incentive mechanisms is outlined in Table 7 and a summary of the different incentive mechanisms adopted across a number of leading offshore wind markets is outlined in Table 9.

Table 7. Incentive mechanism design options

Policy tool	Options	Trade-off	Example
Allocation	Demand-led: Incentive mechanisms are offered to all qualifying generation.	+ Minimises allocation risk for developers, lowering barriers to market entry. - Exposes government to overspend risk.	UK (ROC)
	Capacity constrained: Incentives mechanism contracts are capped by either power capacity or budget.	+ Greater budgetary control for government. - Increases allocation risk for developers.	UK (CfD); NL (SDE+)
Subsidy type	Feed-in tariff: Fixed level of support, independent of the wholesale power price.	+ Stable price reduces risk for generators. - Higher cost to government. - Less compatible with competitive electricity markets.	CH; JP
	Fixed feed-in premium: Fixed level of support, in addition to the wholesale power price.	- Generator exposed to wholesale price volatility. + Predictable government expenditure. + More compatible with competitive electricity markets.	UK (ROC); BE
	Sliding feed-in premium: Top-up payment between fixed strike price and wholesale power price.	- Government exposed to wholesale price volatility. + Predictable generator remuneration. + More compatible with competitive electricity markets.	UK (CfD); NL (SDE+)

Policy tool	Options	Trade-off	Example
	Quota obligation/certificate: Obligations on electricity suppliers to procure renewable electricity, delivered through tradable certificates additional to wholesale price (similar to FIT).	+ Guarantees increasing share of renewable electricity. + Market-based mechanism limits government risk exposure. - Generator exposed to wholesale price volatility.	UK (ROC); BE
Floor price	Floor price: Limits the amount of top-up funding if wholesale prices fall below a given level.	+ Government are insulated from a drop in wholesale prices, reducing risk of overspend. - Higher risk for generators, who will not receive the strike price value if wholesale prices fall.	NL (SDE+)
	No floor price: No constraint on the eligible top-up funding between wholesale and strike price.	+ Government are exposed to a drop in wholesale prices, increasing risk of overspend. - Lower risk for generators, who are guaranteed the strike price value even if wholesale prices fall.	UK (CfD)
Ceiling price	Ceiling: If wholesale prices exceed the ceiling price, the wind farm owner must pay back the difference to the government.	+ Government can recover public expenditure to benefit consumers. - Generators unable to claim upside from high wholesale prices.	UK (CfD)
	No ceiling: If wholesale prices exceed the ceiling price, the wind farm owner receives a windfall above the strike price.	- Government unable to recover public expenditure. + Generators able to claim upside from high wholesale prices.	NL (SDE+)
Repayment intensity	Even spread: Subsidy payments are spread evenly over the project lifetime (e.g. ~20 years).	+ Lower annual government spend in initial years. + Incentivises operational efficiency over full project lifetime. - Longer debt repayment can lead to higher borrowing cost and higher LCOE, resulting in higher aggregated subsidy levels.	UK (ROC); FR
	Front-end loaded: Subsidy payments are shortened to provide quicker payback (e.g. 8-15 years).	- Higher annual government spend in initial years. - Lower incentive to maintain operational efficiency beyond subsidy period. + Shorter debt repayment can lead to lower borrowing cost and lower LCOE, resulting in lower aggregated subsidy levels.	DE (Accelerated model); TWN
Support cap	Time (years): Subsidy eligibility elapses after fixed period of time.	+ Predictable and manageable for government. - Government at risk of overspend from higher load factors. + Generator rewarded for high load factors. - Generator risk of non-payment during downtime.	UK; DE
	Power production (load hours): Subsidy eligibility elapses after fixed amount of electricity generation.	- Less government control over phasing of payment. + Lower risk of curtailment for generators (and government if system balancing is required). - Generators not rewarded for high load factors.	DK; NL

Policy tool	Options	Trade-off	Example
Rate of regression	Shallow: Slow decrease in support levels per allocation round or commissioning date.	+ Lower risk for generators to make long-term investments. - Risk of government overspend / excessive generator profit margins. + Greater certainty of meeting deployment targets.	UK (ROC)
	Steep: Rapid decrease in support levels per allocation round or commissioning date.	- Higher risk for developers to make long-term investments. + Stimulates cost reduction for lower government spend. - Risk of stalling deployment.	UK (CfD)
Site-neutrality	Site-neutral: Support levels are fixed, independent of site conditions.	+ Incentivises the most attractive and lowest cost sites to be developed first.	UK; DK; NL
	Site-specific: Additional support levels are available to sites in deeper water or further from shore.	+ Provides support to develop strategically important development zones. - Higher generation costs will require higher incentives.	DE
Price indexation	Index-inflation: Strike price is adjusted annually for inflation.	+ Guarantees suitable remuneration to reflect changes in the broader economy. - Less predictable cumulative revenue/subsidies.	UK; FR
	No index-inflation: Strike price is fixed, not linked to inflation.	- Real values of revenue not accounted for. + More predictable cumulative revenue/subsidies.	NL; DE; DK

Additional considerations for incentive mechanism design include the tax rate and whether grid connection is the responsibility of the wind farm developers or the transmission system operator (TSO), which will impact on the level of subsidy required. Regarding grid connection, it should be noted that the cost will still be passed on to consumers, either through taxation or energy bills. A discussion on the cost effectiveness of each approach is included in section 3.3 ('Grid policy').

Tax rates are more challenging to influence, but can impact on the investment risk profile. Lower tax rates in countries like the United Kingdom are more attractive than higher rates of taxation in countries like France and the Netherlands. Only Belgium provides a specific offshore wind tax incentive, representing a one-off investment deduction of 13.5% on the acquisition value³⁴.

Auction-based incentive mechanisms

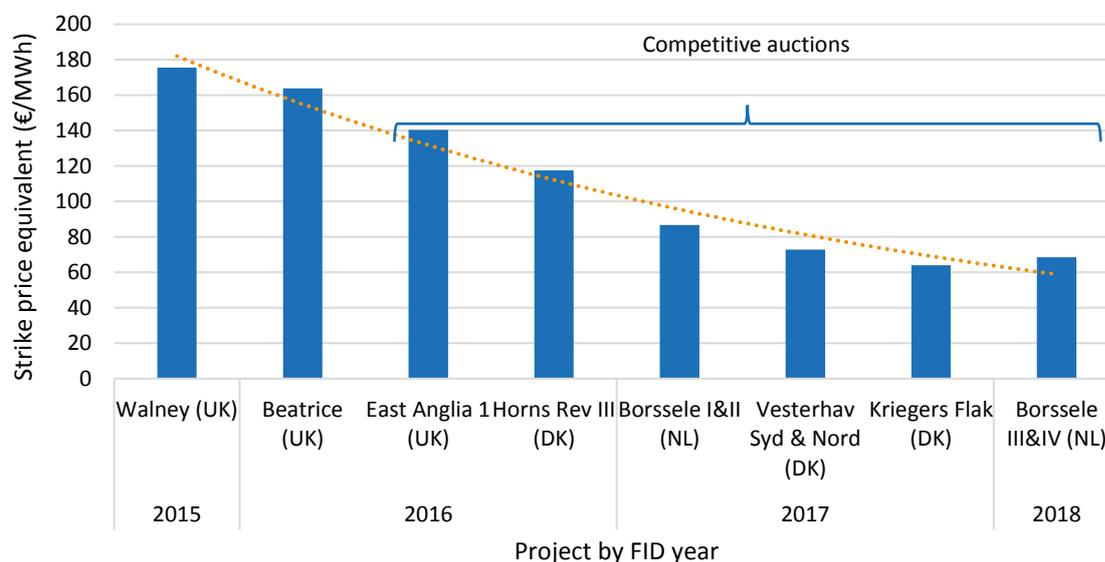
As technologies and markets have matured, competitive tendering has become increasingly prominent, with 64 countries choosing to adopt auction-based systems as the preferred mechanism to assign publically funded support. From 2017, European Union State Aid guidelines will even mandate that energy subsidies be granted through competitive bidding processes.

³⁴ TKI Wind op zee. 2015. *Subsidy Schemes and tax regimes*. Available at: <http://tki-windopzee.eu/files/2015-09/20150401-rap-subsidy.and.tax.policies-pwc-f.pdf>

The transition to competitive auctions is considered a key driver of cost reduction in maturing energy technologies, and has resulted in marked cost reduction in several recent contract awards, including:

- Onshore wind tenders in the USA and Morocco at \$25-30/MWh (equiv. €24-28/MWh)³⁵
- Offshore wind tenders in the Netherlands and Denmark at €50-55/MWh (equivalent to €64-69/MWh with grid connection and development costs included; Figure 12)

Figure 12. Strike price equivalents in European offshore wind projects³⁶



The UK Government estimate that the introduction of competitive auctions through the CfD mechanism will save consumers £250-310m (equiv. €293-363m) per year from the Round 1 auction alone³⁷. Similarly, the transition to competitive auctions in the Netherlands derived strike prices 41% and 54% below the price cap, respectively, which is expected to deliver combined savings of ~€7.4bn over the lifetime of the Borssele I, II, III & IV projects³⁸.

While these early offshore wind auctions have proved successful in creating higher levels of competition and lower bids, it should be noted that the auction process and incentive mechanisms must be designed appropriately to again balance the risk profile between government and developers. For governments, this is essentially a balance between lowest price and the risk of non-delivery. In addition to the design tools captured above, various additional options for policy makers to consider when designing competitive auctions, together with the associated trade-offs, are included in Table 8.

³⁵ RENewEconomy. 2016. *New low for wind energy costs: Morocco tender averages \$US 30/MWh (equiv. €28/MWh)*. Available at: <http://reneweconomy.com.au/2016/new-low-for-wind-energy-costs-morocco-tender-averages-us30mwh-81108>, noting that the US\$ 25/MWh (equiv. €24/MWh) was boosted by a 30% production tax credit.

³⁶ Strike prices in the Netherlands and Denmark include uplift of €14/MWh to account for site development and grid connection costs. It should be noted that strike prices in the UK and Netherlands are fixed for 15 years, while in Denmark support is capped at 50,000 load hours (expected to be equivalent to ~12 years).

³⁷ Renewablesnow. 2015. *Competition body says UK's early offshore wind deals were too costly*. Available at: <https://renewablesnow.com/news/competition-body-says-uks-early-offshore-wind-deals-were-too-costly-483273/>

³⁸ Renewables. 2016. *Borssele bid saves €2.7bn*. Available at: <http://renews.biz/103318/borssele-bid-saves-27bn/>; Dutch News. 2016. *New Dutch offshore wind farm project requires much lower subsidies: minister*. Available at: <http://www.dutchnews.nl/news/archives/2016/12/new-dutch-wind-farm-project-requires-much-lower-subsidies-minister/>

Table 8. Competitive auction design options

Policy tool	Options	Trade-off	Example
Auction cap	Fiscal: A fixed budget is allocated per auction round.	+ Government can achieve more installed capacity per funding round. + Predictable outlay of public funding. - Higher risk for developer regarding project scale.	UK CfD
	Capacity: A fixed level of installed capacity is allocated per auction round.	+ Government can save public investment to deliver desired capacity.	NL
Technology neutrality	Technology neutral: All renewable technologies compete on equal terms.	+ Maximises short-term cost-effectiveness of renewable electricity generation. - Limited support for strategically important energy technologies. - May lead to a market dominated by a small number of technologies. - Offshore wind unlikely to be able to compete against more mature technologies.	NO
	Technology-specific: Carve-outs are made for specific or sub-sets of technologies.	- Higher near-term government spend. + Ability to support strategically important energy technologies. + Offshore wind competitive against other less mature technologies.	NL (SDE+)
Auction format	Pay-as-bid: Bidders receive the strike price they bid in with.	- Government pays out less + Bidders may apply less conservative risk premiums, increasing risk of non-delivery	DE
	Pay-as-clear: Uniform strike price determined by highest successful bid.	- Government pays out more (some projects receive more support than required) + Bidders may apply more conservative risk premiums, reducing risk of non-delivery	UK
Pre-qualification	Pre-qualification round: Initial evaluation round to rule out low quality bids.	+ Mitigates risk of receiving speculative bids - Lower number of bidders reduces competition + Saves development expenditure for uncompetitive developers	UK CfD; DK
	No pre-qualification: All bidders assessed in a single evaluation round.	- Increases risk of receiving speculative bids + Higher number of bidders increases competition - Risk of several developers expending more during bid preparation phase	NL
Bid bond	Bid bond: Bidders must pay a bond in order to enter a tender submission.	+ Mitigates risk of receiving speculative bids - If set too high, can deter bidders, limiting competition	NL
	No bid bond: Bidders can enter a tender at no cost.	- Increases risk of receiving speculative bids + Reduces entry barrier	UK

Table 9. International comparison of offshore wind incentive mechanisms

	UK	Germany	Netherlands	Denmark	France	Belgium	China	Chinese Taipei	Japan
Subsidy type	(i) Renewable Obligation Certificates (ROC): Feed-in premium (fixed) (ii) Contract for Difference (CFD): Feed-in premium (sliding)	(i) EEG 2014: Feed-in premium (sliding) (ii) EEG 2017: Feed-in premium (sliding)	SDE+: Feed-in premium (sliding)	Feed-in premium (sliding)	(i) Rounds 1 & 2: Feed-in-Tariff - Rounds 1 & 2 (ii) Round 3: Feed-in-Premium	Feed-in premium (sliding)	Feed-in tariff	Feed-in tariff	Feed-in tariff
Subsidy allocation	(i) Demand-led (ii) Competitive (budget constrained)	(i) Demand-led (ii) Competitive (capacity constrained)	Competitive (capacity constrained)	Competitive (capacity constrained)	(i) Rounds 1 & 2: Competitive (capacity constrained) (ii) Round 3: Competitive (capacity range)	Demand-led	Demand-led	Demand-led	Demand-led
Site allocation	(i) Zoning (ii) Zoning	(i) Zoning (ii) Site-specific	Site specific	Site specific	Zoning	Zoning	Open-door	Zoning	Open-door
Subsidy level	(i) 1.8-2.0 ROCs (ii) Determined by auction	(i) €150/MWh (20 yrs) / €190/MWh (8 yrs) (ii) Determined by auction	Determined by auction	Determined by auction	Project specific	(i) €138/MWh excl. grid connection (ii) €150/MWh incl. grid connection	Nearshore: 0.85 CNY/kWh Intertidal: 0.75 CNY/kWh ⁽¹⁾	\$199/MWh (20 yrs) Or \$233/MWh (10 yrs) & \$144/MWh ⁽²⁾	¥36/kWh
Support duration	(i) 20 years (ii) 15 years	(i) 20 years (front-loaded for first 8 or 12 years) (ii) 15 years	15 years (+1 year for banking if full load hours not met)	50,000 load hours (~12 years)	20 years	20 years	20 years	(i) 20 years (fixed) Or (ii) 20 years (front loaded for 10 years)	20 years
Floor price	(i) No (ii) No	(i) Yes (ii) Yes	Yes	No	No	No	No	No	No
Ceiling price	(i) No (ii) Yes	(i) No (ii) No	No	No	No	No	No	No	No
Grid connection	(i) Generator build (ii) Generator build	(i) TSO build (ii) TSO build	TSO build	TSO build	TSO build or Generator build	(i) TSO build Or (ii) Generator build w/ uplifted tariff	Generator build	Generator build	Generator build
Corporate tax rate	20%	22.4-32.4%	25%	22%	33%	33% (13.5% deduction on acquisition value)	25%	17%	32%

⁽¹⁾equiv. € 0.12/KWh and € 0.10/KWh ⁽²⁾ €188/MWh, €220/MWh, and €136/MWh

3.4.3 Lessons learned

In general, the remuneration systems adopted in Europe have proved successful in creating an attractive investment environment for developers. This has been reflected in high deployment volumes in countries with support schemes that limit allocation and investment risk, such as the UK. However, several countries have had to scale back deployment targets, in part due to inadequate incentive mechanisms that failed to stimulate the desired level of activity. A number of lessons can therefore be learned from past experience.

Governments should engage with industry and use early projects to set the right level of support

Setting appropriate levels of subsidy support for new technologies can be challenging for policymakers. In Europe, cases have been seen where remuneration support has been too low to stimulate activity. In Germany, for example, the level of support set under the EEG FIT in 2004 was too low to provide a suitable return on investment for project developers. Despite increasing the tariff in 2008, it required a further increase in 2012 to provide greater certainty to developers of the economic viability of their projects. While influenced by other market factors which led to increased costs, this iterative approach did not provide the stability and certainty needed for investors.

To mitigate these risks, governments in emerging markets may need to accept higher costs in early projects to catalyse the sector, but can limit the scale of build out to minimise their risk exposure. Engaging with industry and mandating a certain level of data sharing on project costs, notwithstanding commercial sensitivities, can then help to inform the design of incentive mechanisms for long-term deployment. For example, the UK successfully implemented a capital grants scheme to prove the technology and collect data to inform future design, manifested in the highly successful Renewable Obligation, which in turn has informed strike price levels in the Contracts for Difference regime.

Likewise, having learned from past experience, Germany will be using the upcoming Phase 1 auctions in 2017 to determine the prescribed strike price cap for future auction rounds. However, caution should be taken with this approach not to undermine effective bidding (i.e. discouraging low bids in early auction rounds).

Front-loading subsidy payments can reduce investor risk and deliver lower cost of energy

As financing for offshore wind has evolved from grant and balance sheet funding to project financing models with increasing debt, so too have incentive mechanisms evolved to provide a quicker return on investment (see Box 17). Front-loading subsidy payments to enable generators to repay loans quicker leads to a lower cost of capital and lower cost of energy for the project. While higher up-front payment is higher risk for government, this is balanced with the opportunity to reduce the overall level of subsidy required.

It should be noted that for developers opting for balance sheet financing, a longer subsidy duration may be preferable. Spreading subsidy payments over the project lifetime can also incentivise efficient wind farm operation over a longer period, and this may be preferable with developers adopting a balance sheet financing approach which is less impacted by debt repayment.



Box 17: Accelerated feed-in tariffs in Germany and Chinese Taipei

An example of front-loaded subsidy support is seen in the German accelerated FIT model, under the EEG 2014, which includes a higher tariff (€190/MWh) for the first 8 years of operation, before dropping to a lower tariff (€35/MWh) for the following 12 years. This contrasts with the standard FIT of 12 years at a modestly higher rate (€150/MWh) before falling to the same base level (€35/MWh) for the final 8 years of operation.

The accelerated tariff is also subject to an annual €10/MWh degression from 2017 to 2019, while the base tariff will decrease by €5/MWh over the same period. From 2021, tariffs will be determined by competitive tender.

A similar approach is being adopted in Chinese Taipei, where an attractive accelerated tariff of US\$233/MWh (equiv. €220/MWh) is available for the initial 10 years, followed by a lower tariff of US\$144/MWh (equiv. €136/MWh) for the next 10 years. Alternatively, a fixed tariff of US\$199/MWh (equiv. €188/MWh) is available for 20 years. Even though the average tariff, and total support, is higher in the fixed model, the ability to receive more up-front payment in the accelerated model is likely to make this preferable for developers, and at a lower total cost to government.

An appropriate cap or assumption needs to be set on power production

When assigning public funding to support renewable energy through remuneration systems, governments must either set a cap or make an assumption on the level of power production expected. Determining an appropriate number of load hours or capacity factor is critical and if poorly designed can result in either limited incentives for generators or government overspend.

In the UK, no cap is set on power production, with generators eligible to receive top-up funding through the CfD mechanism for every unit of electricity generated. This rewards generators for maintaining high output and optimising the performance of the wind farm. However, the UK government has been criticised in the face of overspend to the Levy Control Framework as a result of applying an estimate on anticipated load factors that has proved to be too low. Having applied a load factor of just 37.7% when determining the allocated budget for CfD contracts, high load factors exceeding this level have resulted in higher payments to generators. Upcoming CfD rounds will adopt a revised load factor assumption of 47.7%.

Emerging markets should carefully consider when to adopt competitive auction systems

Recent auction prices have demonstrated the impact of increased competition on price and with over 12 GW of installed capacity, offshore wind technology has matured as a proven and low risk asset class. For this reason, some emerging markets may consider moving directly to competitive auction-based systems, following the same trend seen in onshore wind and solar PV, where countries like Chile, Argentina, and South Africa have successfully adopted competitive systems from the outset.

However, caution should be taken in adopting a similar strategy with offshore wind, which involves more complex offshore construction methods and may require considerable up-front infrastructure investment. Squeezing developers and suppliers on price from the outset increases the risk of non-delivery, which could stall deployment (see Box 18).



Box 18: Incentive mechanisms in China

China has experienced considerable project delays from adopting incentive mechanisms that have resulted in feed-in tariffs too low to stimulate deployment. The decision to move directly to competitive allocation led to low bids in early tender rounds, which have made projects economically unviable. Despite running the first tender round in 2010, none of the 4 successful projects progressed until the government intervened with the introduction of higher fixed tariffs. The delays caused have seen national deployment targets scaled back considerably. Introduction of the fixed feed-in tariff in 2014 has stimulated more activity, with a steady regression outlined for projects commissioned after 1st January 2017.

Table 10. Offshore wind feed-in tariffs in China

Project type	First concession round FIT (CNY per KWh)	Revised FIT – before 2017 (CNY per KWh)	Revised FIT – from 2017 (CNY per KWh)
Nearshore	0.7047 - 0.7370 (equiv. €0.097 – 0.102/KWh)	0.85 (equiv. €0.12/KWh)	0.80 (equiv. €0.11/KWh)
Intertidal	0.6235 - 0.6396 (equiv. €0.086 – 0.088/KWh)	0.75 (equiv. €0.10/KWh)	0.70 (equiv. €0.098/KWh)

In addition to the feed-in tariffs outlined above, some provinces have decided to provide additional support to stimulate local activity. For example, the Shanghai Municipal Government are offering an additional 0.2 CNY/kWh for offshore wind projects, which is triggering increased deployment in the Shanghai area.

In emerging markets with limited existing supply chain capabilities and a lack of experienced market players, adopting fixed remuneration support would reduce the risk of non-delivery, enabling the domestic market to build capability and construction volume before transitioning to competitive auction systems. For markets with strong supply chain capabilities or an ability to attract experienced industry players, competitive auctions may be possible from the outset, but policy frameworks will need to be designed to balance the risk profile accordingly. For example, a greater level of government de-risking may be required to limit the scope of responsibilities for developers and reduce the risk of non-delivery (e.g. Denmark; see Box 19).



Box 19: Incentive mechanisms in Denmark

Denmark has adopted a competitive auction-based system since 2005. The Danish government has adopted a more interventionist and centralised approach, whereby government bodies undertake considerable site development work, including site surveys, consenting, permitting, and construction of grid assets. Projects are then tendered on a site-specific basis at pre-construction phase. This approach is arguably more favourable when moving to competitive auction systems in immature markets, particularly where there is limited experience of project development. However, it should be noted that some developers have a preference for greater control over the development process.

Table 11. Offshore wind tenders in Denmark

Project	Auction Year	Project capacity (MW)	Strike price (øre/kWh)
Horns Rev 2	2004-05	209 MW	51.8 (equiv. €6.97)
Rodsand 2	2008	207 MW	62.9 (equiv. €8.46)
Anholt	2009-10	400 MW	105.1 (equiv. €14.14)
Horns Rev 3	2013-15	392 MW	77.0 (equiv. €10.36)
Vesterhav Syd & Nord	2016	350 MW	47.5 (equiv. €6.39)
Kriegers Flak	2016	600 MW	37.2 (equiv. €5.00)

Transitions from fixed-remuneration systems to competitive auctions can introduce higher allocation and price risk and need to be managed carefully

The transition from fixed remuneration support to competitive auction systems is a logical evolution for utility-scale renewable energy technologies, helping to drive down cost and prepare for a ‘subsidy free’ future. However, this transition can be highly disruptive if not managed carefully. Allocation risk, in particular, in moving from demand-led to competitive allocation can have a considerable impact on the risk profile for developers (see Box 20). Particularly in countries adopting a decentralised approach to offshore wind development, whereby developers must take on considerable risk and expense in developing the site, the uncertainty of a competitive auction process could be a major deterrent to investment.


Box 20: UK transition from the Renewable Obligation to Contracts for Difference

The UK has experienced a considerable shift in the design of incentive mechanisms for offshore wind. Under the demand-led approach of the Renewable Obligation, allocation and price risk was low, with predictable remuneration support available (albeit subject to wholesale prices and RO certificate auction pricing). This greater certainty of obtaining remuneration support was a key driver in stimulating the market and encouraging private investment to develop UK sites, at a development cost of up to £70m (equiv. €82m) per project. However, the transition to the capacity constrained and competitive CfD regime has significantly increased allocation risk, providing lower guarantees of a route to market, as well as price risk, given uncertainty over the strike price to be attained.

In order to maintain market confidence during the transition between regimes, the UK government introduced a Final Investment Decision Enabling Round for Renewables (FIDeR), which awarded early CfD contracts to five offshore wind projects in advanced stages of development, totalling >3.1 GW capacity). Despite reducing investment risk in several projects, the contracts were awarded fixed strike prices without competition, which has led to criticism in the wake of low strike prices achieved in the first CfD auction round and elsewhere across Europe. The Competition and Markets Authority's estimate that the FIDeR CfD contracts for offshore wind may have cost £250-£310m (equiv. €293 – 363m) a year more than if they had been subject to price competition.

Table 12. UK offshore wind contract for difference (CfD) awards

	FIDeR CfD contract awards					CfD Round 1 auction	
	Burbo Bank Extension	Dudgeon	Walney Extension	Beatrice	Hornsea 1	East Anglia 1	Neart na Gaoithe
MW	258	402	660	664	1200	714	448
€/MWh	£150 (€176)	£150 (€176)	£150 (€176)	£140 (€164)	£140 (€164)	£120 (€141)	£115 (€135)
Commissioning	2017	2017	2017/18	2018/19	2019/20	2019/20	2020/21
Competitive?	No	No	No	No	No	Yes	Yes

To maintain investor confidence, industry needs visibility and transparency of changes to support policies. This should include how much time or deployment should be expected before a transition to competitive auctions is made. Providing a long lead time for developers to assess the viability of their projects in future auction rounds can help to inform investments decisions, and limit potential sunk development costs in less attractive projects. This level of planning also enables the supply chain to adapt and plan investment in new facilities and products accordingly.

Technology neutrality/competition should align with national objectives

The level of allocation risk a government is willing to assign to developers is dependent on national objectives. Where governments are looking to deliver energy at lowest cost to consumers, particularly over the short-term, a technology-neutral approach can ensure that subsidy contracts are awarded to the most competitive forms of generation. This approach is adopted in Norway, where high energy security and low carbon electricity is provided through considerable hydroelectric power resources. Consequently, there has been very little offshore wind deployment in Norway beyond a handful of innovative prototype demonstrations.

For countries with particular long-term strategic aims (e.g. industrial and energy strategies), governments may choose to ring-fence subsidy budgets for technologies which may not be competitive in the short-term. In the UK, a hybrid approach is adopted whereby CfD auction rounds are divided into two pots – one for established energy technologies (e.g. onshore wind, solar PV) and another for strategically important less-established technologies (e.g. offshore wind, biomass CHP, wave & tidal). Meanwhile, in the Netherlands, the SDE+ mechanism includes a separate carve out specifically allocated to offshore wind.

Ultimately, the approach adopted should reflect national objectives and form part of a country's long-term energy strategy. But with EU State Aid guidelines pushing towards greater technology-neutrality, there may be increasing pressure for offshore wind to compete with other electricity generation sources, particularly if costs continue to fall.

Competitive auctions should be designed to deter speculative bids and penalise non-delivery

While competitive auctions are an effective tool to drive cost reduction, without the necessary breaks in place a government can be exposed to speculative low bids that result in non-delivery, as seen in the first concession tender in China. To limit exposure to such risk, governments can design tendering systems to deter speculative bids and penalise non-delivery (see Box 21). Policy instruments include:

- **Pre-qualification** rounds consist of an initial evaluation round to remove uncompetitive or unrealistic bids. This can limit developer expenditure in preparing full tenders, but also reduces the level of competition in the final bidding process.
- **Bid bonds** represent a financial commitment from prospective developers to enter a tender round. The size of the bid bond must strike a balance between the level needed to suitably penalise non-delivery whilst not creating an entry barrier which could limit competition.
- **Financial penalties** for delays or non-delivery following contract award can provide further safeguards to governments, but can deter bidders and reduce competition.



Box 21: Offshore wind tender design in the Netherlands and Denmark

Despite both adopting more centralised development models and auction-based systems, tender submission requirements differ between the Netherlands and Denmark. Danish offshore wind tenders include a pre-qualification round and bid bonds of ~€10m per 100 MW to deter speculative bids and ensure that bidders have suitable competencies to deliver the project, should they be successful. This reduces the risk of non-delivery but can also reduce the level of competition between bidders. In contrast, recent tenders in the Netherlands have not included a pre-qualification round and have assigned a lower bid bond of €10m per 350 MW in order to maximise competition. The bond increases to €35m within one year within which developers should reach financial close.

Denmark previously included financial penalties for delays to strict delivery schedules, including the auction for Anholt wind farm. However, these have since been withdrawn due to the additional risk for project developers leading to low interest and low competition between bidders and resulting in more conservative strike prices, as evident in the higher tariff for Anholt wind farm (see Table 7). In the Netherlands, a financial penalty applies through lost remuneration if wind farms are connected after the fixed start date for subsidy support.

Relaxing delivery milestones can limit risk exposure for developers

Incentive mechanisms are often awarded on the condition of meeting prescribed milestones, set by the awarding authority. These milestones ensure that developers move forward with their projects and meet government timelines for securing online capacity. However, overly aggressive milestones can increase the risk profile for developers, particularly milestones early in the post-award process (e.g. United Kingdom CfD milestones; see Box 22).



Box 22: UK Contract for Difference milestone conditions

In the UK, project developers must have spent 10% of their pre-commissioning budget within 1 year of securing a CfD contract, which in some cases can mean that contracts need to be in place with suppliers before the auction process even begins. As well as adding risk to both developers and suppliers, this can increase development expenditure for companies looking to line up supplier contracts before a final investment decisions have been made on the project. Greater flexibility post-contract award would therefore be beneficial.

Government-backed banks can de-risk investments in offshore wind

Access to finance is a key enabler for the industry, particularly as project size and developer project portfolios increase. To realise the significant growth potential for offshore wind, developers need to be capitalised in such a way that they can continue to invest in new projects. As project portfolios increase, developers no longer have the capital required to build and hold these assets, so are reliant on external investors to free up capital reserves. Several European governments have therefore created dedicated banking institutions to invest in low carbon technologies, including offshore wind. Banks such as KfW in Germany, EKF in Denmark, the Green Investment Bank in the UK (see Box 23), and the European Investment Bank, have all made sizeable investments in offshore wind farms, during both construction and operational phases. By investing on fully commercial terms, these banks have demonstrated the attractiveness of offshore wind investments that has attracted a more diverse range of financiers, including pension funds.

State banks can therefore play a critical role in reducing financing costs for developers, driving down cost of energy and freeing up the necessary capital to make continued investment in expanding project portfolios. However, state banks need sufficient capital resources to have a major impact.



Box 23: UK Green Investment Bank

The UK Green Investment Bank was created in 2012 by the UK Government, its sole shareholder, to invest in the offshore wind, waste and bioenergy and energy efficiency sectors. Since being capitalised with an initial £3.8bn (equiv. €4.5bn) of public funds, the GIB has invested almost £7bn (equiv. €8.2bn) in 46 projects across the UK. This has included ~£1.3bn (equiv. €1.5bn) invested in 8 offshore wind projects with a total capacity of 2.9 GW.

**Green
Investment
Bank**

The GIB has pursued a dual strategy of financing construction projects to help the UK offshore wind development pipeline and financing operational projects to free up developers' capital to re-invest in the development and construction phases of projects.

The GIB has also recently created a subsidiary, UK Green Investment Bank Financial Services Limited, the world's first dedicated offshore wind fund. The fund has been established with the aim of attracting capital into the UK's offshore wind sector, with a target size of £1bn (equiv. €1.2bn). Attracting new capital and creating a liquid market for operating assets helps to reduce long-term cost of finance by enabling developers to sell down their stakes and use the proceeds to finance new projects.

3.5 SUPPLY CHAIN DEVELOPMENT

- **Suppliers need long-term visibility and certainty of market scale**
- **Local content requirements can support domestic industrial policy, but are likely to be a barrier to cost reduction**
- **Bottom-up initiatives may be more effective in balancing government objectives to reduce costs and maximise local economic benefit**
- **Public investment in infrastructure can catalyse private sector investment, leading to the creation of supply chain clusters**
- **Business support programmes can attract new market entrants and improve supplier competitiveness**
- **Specialisation, through leveraging existing capabilities and investing in innovation, can create competitive advantage for domestic suppliers**
- **While Europe has been relatively insulated from supply chain bottlenecks due to cumulative market scale and regional cooperation, isolated emerging markets (e.g. USA, Japan, Chinese Taipei) with limited market size will face greater challenges**
- **International and inter-state cooperation can remove entry barriers for emerging markets**

Securing economic and industrial benefits is often a key motivation for policy makers when assigning public funding to support offshore wind development. Offshore wind projects are capital intensive, representing high potential to create jobs and stimulate business, both at home and overseas through export opportunities. A range of policy tools exist to enable governments to support domestic companies, some of which may clash with parallel goals of maximising deployment levels and driving cost reduction. These three aims are often a high priority for government officials, but are rarely mutually compatible. The degree of interventionism and types of policies introduced is therefore highly dependent on a government's primary objectives and the extent to which energy policy aligns with industrial strategy.

Across Europe, a variety of approaches have been adopted by different countries. Some, such as the UK, have adopted a more open and free-market approach, with deployment and cost reduction prioritised over industrial benefits. Others, such as Denmark, Germany, and the Netherlands, have taken a more interventionist approach, strategically aligning energy policy with industrial aims. Some countries have gone to even greater lengths to secure local economic benefits, with stringent local content requirements imposed (e.g. France). Meanwhile, other countries have managed to exploit favourable market economics to play a major role in the supply chain, despite limited deployment levels (e.g. Spain, Poland).

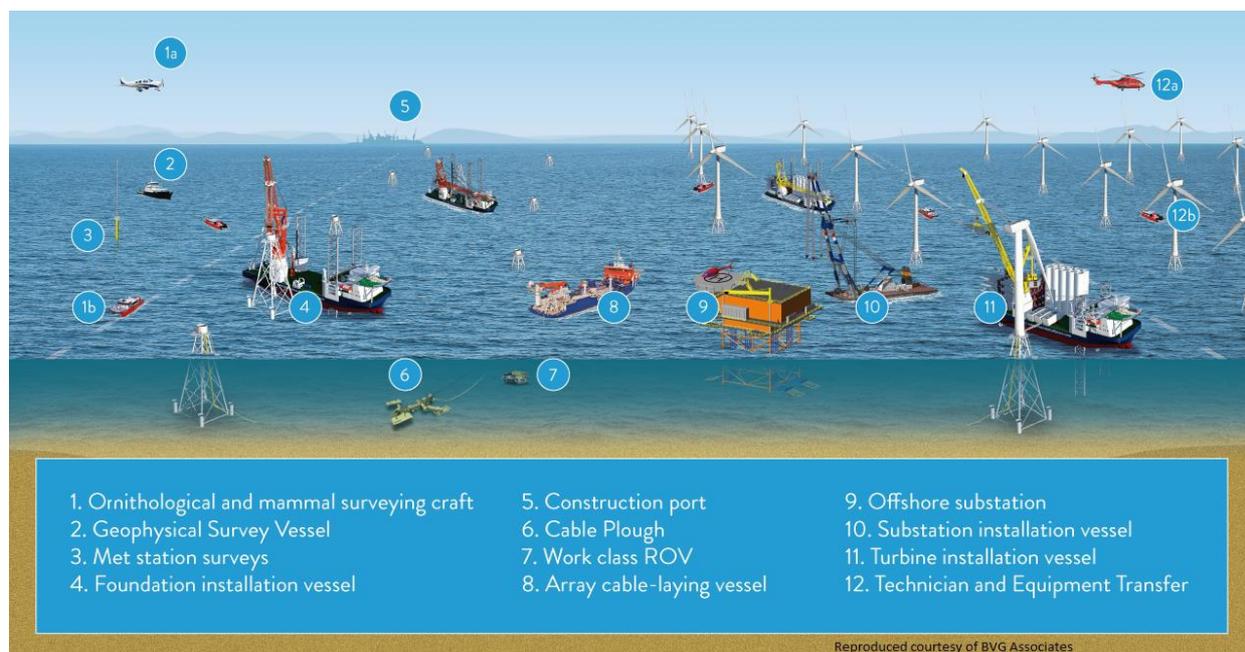
3.5.1 Offshore wind supply chain

Offshore wind development requires more extensive and complex supply chains than other renewables, such as onshore wind and solar PV. In addition to challenging offshore construction methods, increasing project size and turbine rating is adding more stringent requirements to project logistics and the facilities and components required.

Certain components are more easily transported than others, enabling importation from manufacturing bases across a given region and greater market competition. The scale of the facilities required and limited demand in single countries means that suppliers will typically concentrate production in a small number of manufacturing facilities which can service the wider market. This can create challenges for governments in maximising local content, particularly if domestic suppliers are uncompetitive in procurement tenders.

However, several aspects of the supply chain are by their nature more localised, such as installation and O&M ports. Fabrication of larger components is also preferable in closer proximity to port bases, often leading to the development of industrial clusters for offshore wind development. The high cost of port upgrades and large manufacturing facilities is often a high entry barrier for emerging markets, particularly if there is uncertainty over the anticipated scale of build out. Government intervention can often be used effectively to de-risk investments and create enabling infrastructure to attract further private investment. A number of policy tools available to governments to increase local content and improve competitiveness are outlined in section 3.5.2 below.

Figure 13. Guide to an offshore wind farm



Source: BVG Associates

3.5.2 Policy tools

Supply chain policies introduced by governments will reflect both the prioritising between deployment, cost reduction, and industrial benefits. A country's approach to supply chain policy is also heavily influenced by local context, particularly the capabilities and gaps that exist in the domestic supply chain. Proximity to neighbouring markets is also an important factor, with more isolated markets less able to leverage nearby supply chains. The need to address key supply chain bottlenecks and introduce enablers will therefore influence the level of government support needed and policy approach adopted. A range of policy tools are outlined below:

- Market scale and visibility:** High levels of deployment attract inward investment and the staging of nearby facilities. This is particularly applicable to large components and infrastructure, which is less easily exportable. Developers and suppliers therefore look for close proximity to project sites to improve logistics and limit transportation costs. Although fairly low in terms of intervention, providing long-term visibility of market scale can be challenging for governments, but a range of options exist to instil investor confidence (see section 3.1).
 - Example:** High deployment and a strong forward pipeline in the UK has attracted investment from suppliers such as Siemens, who have committed to developing a new blade manufacturing facility in Hull. The proximity of the facility to neighbouring North Sea countries added to the site's attractiveness.
- Local content requirements:** A more interventionist approach from government is to attach minimum local content requirements to incentive mechanism contract awards. This can range from considerations in the evaluation criteria to subsidy top-ups and the submission of supply chain plans.

- **Example:** Tender rounds 1 and 2 for projects in France applied a high weighting on local content (40% in the evaluation criteria) although this provision was subsequently removed for Round 3 (see Box 24).
- **Example:** In Denmark, developers are obliged to assign 20% of construction costs to Danish firms and offered an enhanced subsidy (0.01 øre/kWh)³⁹ if local content surpasses 30%.
- **Example:** In the UK, In order to submit tenders for CfD auctions, prospective developers must submit supply chain plans, which include targets for local content. However, it is unclear how these plans will be enforced if developers fail to meet these targets.
- **Infrastructure investment:** Governments can provide fiscal stimulus (i.e. grants, low-interest loans, tax relief) to develop key enabling infrastructure, such as ports. In addition to meeting construction requirements, these investments can attract private investment in companies looking to leverage the facilities and position themselves within dedicated hubs and clusters for offshore wind development.
 - **Example:** Government bodies in Germany have injected considerable investment into developing port infrastructure, which has resulted in ports like Cuxhaven and Bremerhaven establishing themselves as leading hubs for the sector.
- **Business and innovation support:** Grants and low-interest loans can also targeted to local businesses and innovators to develop new products and services for the sector. As well as funding support, this can also involve identifying synergies with other industries, communicating market opportunities, and facilitating brokering between industry players.
 - **Example:** The GROW initiative in the UK has supported a number of businesses to develop products and services for the offshore wind market (see Box 26).
 - **Example:** TKI in the Netherlands works closely with SMEs, academia, and industry to support Dutch companies in the sector, creating campus environments for start-ups to collaborate when developing technology innovations.
- **Training:** Offshore wind entails complex and high risk offshore activities that require highly skilled professionals. Public support can therefore be channelled towards education institutions and bespoke training centres for offshore wind and related industries.
 - **Example:** A network of National Wind Farm Training Centres have been set up in conjunction with industry body, RenewableUK.

Table 13. Impact of government supply chain intervention

Policy tool	Government intervention	Impact: Local supply chain	Impact: LCOE
Market scale and visibility	High		
Local content requirements	High		
Infrastructure investment	High		
Business and innovation support	Medium		
Training	Low		

³⁹ Equiv. €1.3/MWh

3.5.3 Lessons learned

Suppliers need long-term visibility and certainty of market scale

Market scale and visibility is consistently seen as the most important factor for suppliers. Medium to long-term visibility attracts companies to enter the offshore wind supply chain, providing the certainty needed to invest in new facilities, products, and services. Particularly given the high cost and long-lead times to develop key enabling infrastructure, such as ports, manufacturing facilities, and vessels, suppliers need confidence that the market will offer sufficient business opportunities over extended timescales to secure a return on investment. High and consistent levels of deployment also ensures sufficient market share for a larger number of suppliers, increasing competition to drive down costs.

WindEurope estimate that ~4-7 GW of annual installed capacity is needed in Europe to maintain a sufficient project pipeline that will sustain competitive market forces and deliver on cost reduction targets. Existing national targets suggest that ~2-3 GW of annual installed capacity can be expected in the early 2020s, indicating a gap that needs to be filled through more ambitious deployments targets or new market entrants (i.e. Baltic nations). In emerging markets outside Europe, achieving the levels of scale necessary to justify substantial investment decisions is even more challenging. International and inter-state cooperation is therefore vital to replicate the economies of scale derived across the North Sea region.

Local content requirements can support domestic industrial policy, but are likely to be a barrier to cost reduction

Introducing local content requirements is a direct means of increasing economic and industrial benefits. However, this approach is rarely compatible with delivering low project costs due to limited supplier competition and the high cost and long lead time in having to develop new manufacturing facilities. The restriction that this adds to procurement strategies for developers is a key reason why very few countries have enforced stringent requirements to date.

From a wider supply chain and cost reduction perspective, it is also unrealistic and uneconomical to set up new production facilities in every country to meet local content demands. Local content is also constrained by EU competition guidelines which aim to promote the free movement of goods and fair procurement practices across member states.

Despite these potential restrictions and dis-benefits, for countries looking to closely align energy and industrial policy, local content requirements can be introduced to provide greater guarantees of maximising domestic economic benefits (see Box 24). But to deliver cost reduction, these constraints either need to be relaxed or high levels of national deployment will be necessary to achieve sufficient economies of scale.



Box 24: French local content requirements

In its first two offshore wind rounds (2011 & 2013) France placed a high emphasis on maximising the domestic economic benefits from offshore wind development. In the tender evaluation process, environmental impact was weighted at 20%, while local content was given the same weighting as price (40%). The tariffs negotiated between Government and bidders for these rounds have not been made publicly available, but are believed to be higher than other projects elsewhere in Europe. The Round 1 and Round 2 windfarms have yet to reach commissioning stage although it is understood that progress is ongoing.

The French policy has been successful in attracting new manufacturing facilities and upgrades to French ports, despite delays and speculated high costs incurred. For example, Alstom is building production facilities in Cherbourg and Saint-Nazaire and Adwen is developing facilities in Le Havre and Rouen. The first Alstom turbines from Saint-Nazaire have been delivered to the Block Island projects in the United States, highlighting the export opportunities for the local supply chain.

For its Round 3 call, France changed the terms and conditions and has removed local content as an evaluation criteria (henceforth the primary evaluation criteria is price.) Round 3 also sees a shift to feed-in-premium from the feed-in-tariff in Rounds 1 & 2. Furthermore Round 3 involves initial pre-selection, followed by competitive dialogue with a view to reducing costs as much as possible, prior to the final bidding stage.



Source: Alstom

Public investment in infrastructure can catalyse private sector investment, leading to the creation of supply chain clusters

The construction of large scale offshore wind projects often necessitates considerable investment in port infrastructure. These ports often develop into hubs for fabrication facilities, leading to the formation of offshore wind supply chain clusters. The high market share of German and Dutch companies in the offshore wind supply chain is partly attributed to investing ahead of needs, creating the enabling infrastructure to attract companies and exploit first mover advantage. This has been facilitated both by the existence of parallel industries, but also to a large extent by public ownership of ports in Germany and the Netherlands (see Box 25). This contrasts with the UK, where private ownership of ports creates a stronger need to see orders before investment can be made.

Where private ownership is present, governments (national, regional, and local) should introduce fiscal incentives (i.e. grants, low-interest loans, tax breaks) to encourage longer-term strategic investments. For example, public-private partnerships consisting of co-investment from port owners and regional development funds has been effective in funding port expansion in the UK (e.g. Great Yarmouth).

The provision of suitable port facilities can limit project costs for developers, ultimately leading to lower strike prices that can re-balance up-front public expenditure. The long lead-time to undertake upgrades means that governments should undertake port assessments early on, in consultation with relevant port authorities and project developers.



Box 25: Port infrastructure building in Germany – Bremerhaven

Several German ports have received public funding to redevelop port infrastructure to service North Sea and Baltic Sea offshore wind developments. Bremerhaven, in particular, has established itself as a major hub for offshore wind. The transformation from economic decline to booming industrial growth is routed in a series of strategic investments to regenerate the area and tap into the opportunities emerging from the growing offshore wind sector. Driven by North Sea offshore wind deployment targets exceeding 25 GW by 2030, initial investments of ~€250m were supplemented by a further €180m in 2010 from the Federal Land of Bremen to add a quayside dedicated to offshore wind activities. There are also plans for the construction of the dedicated Offshore Terminal Bremerhaven, which would consolidate and improve Bremerhaven's position as an industrial powerhouse in the offshore wind sector.

These investments have catalysed considerable inward private investment with several wind energy companies setting up business in Bremerhaven. A highly specialised wind energy cluster has emerged, with particular expertise in the serial manufacture of offshore wind turbines and components. In addition to manufacture, the port has developed into a leading centre for research and development, with new turbine models being tested ahead of commercial deployment. The power generated from these prototype installations has also helped the city to achieve its own decarbonisation targets.



Source: Eurogate

Business support programmes can attract new market entrants and improve supplier competitiveness

EU State Aid regulations and competition law pose a challenge to governments in increasing local content in commercial projects. Rather than mandating local content, many governments have turned to applying targeted support for businesses to improve their competitiveness in the global marketplace. Business support programmes are typically led by employment and trade bodies and can include:

- Funding to develop innovative products
- Communicating the business opportunities presented by offshore wind
- Facilitating brokerage events between suppliers and prospective customers
- Trade missions to overseas markets
- Business incubation support

This softer, bottom-up approach is arguably more aligned with cost reduction efforts by ensuring that suppliers are exposed to competition and encouraged to develop new innovative products and services (see Box 26).



Box 26: GROW initiative

In response to limited involvement of UK suppliers in early projects, the UK Government has introduced a number of initiatives with the aim of increasing local content to ~50%. One of the more successful was the GROW Offshore Wind initiative, backed by ~£20m (equiv. €23m) from the Regional Growth Fund to provide support to SMEs with the capability to enter the offshore wind sector.

The programme provided companies with access to market insights, funding grants, and tailored support, based on close interaction with customers to understand industry needs, as well as access to a national network of technology centres. Collaboration between the four delivery bodies – RenewableUK, Grant Thornton, the Advanced Manufacturing Research Centre, and the Manufacturing Advisory Service – also ensured that contract opportunities were identified and pursued to maximise opportunities for UK companies.

GROW: OFFSHORE WIND
Funding for suppliers to
the offshore wind market

mas
manufacturing advisory service

Specialisation, through leveraging existing capabilities and investing in innovation, can create competitive advantage for domestic suppliers

Supply chain development in Europe has been categorised by specialisations across different countries to service a single European market. For example, Denmark and Germany have been able to take advantage of their world-leading status in onshore wind to dominate the turbine market (e.g. Siemens, Vestas, Senvion, Areva) and the Netherlands has benefited from a rich history in the maritime sector (e.g. Van Oord, Smulders, SIF, VSMC). The UK has been less successful in the goods market, but has developed a strong services offering in the form of leading engineering consultancies, as well as some specialist companies in areas such as cable supply (e.g. JDR Cables).

Similar trends are being observed in emerging markets overseas. China, for example, has placed a strong emphasis on building the capability of local suppliers, leveraging their position as the largest onshore wind market. Turbine manufacturers such as Goldwind, Sinovel, Shanghai Electric, XEMC, and MingYang are all developing models for the offshore wind market.

As well as leveraging local capabilities, some countries may be able to exploit unique environmental conditions to establish niche capabilities. For example, in Japan companies are developing technology solutions which can operate with resilience to extreme events, such as earthquakes and typhoons.

International and inter-state cooperation can remove entry barriers for emerging markets

The different specialisations seen in Europe have partly been made possible by the close proximity of neighbouring markets. For more isolated emerging markets overseas, this could place increasing pressures to develop the requisite supply chain capabilities to deliver offshore wind cost-effectively. Without high levels of domestic deployment, greater isolation is likely to result in higher project costs and require even greater public support to develop suitable infrastructure. This could prove a major barrier to developing offshore wind industries, particularly in formative years when deployment is low. Increasing cooperation between countries and states to form larger regional supply chains can lower the risk of supply chain bottlenecks that drive up costs.

3.6 INNOVATION SUPPORT

- **Strategic identification and prioritisation of technology innovation needs can focus R&D efforts**
- **Creating close ties between academic research centres and industry can maximise market penetration of novel technologies**
- **Industry-led collaborative R&D programmes can maximise the impact of public and private funding**
- **Involving financial institutions and lending advisers early in the R&D process can mitigate high risk perception of new technologies**
- **Policies should be designed to enable integration of technology demonstrations in commercial projects**
- **A balance of innovation support should be maintained across technology readiness levels**

Technology innovation is key to overcoming technical challenges, developing windfarms in more challenging site conditions, and reducing cost of energy for offshore wind. Significant progress has been made across Europe to develop commercial wind farms that can operate in challenging offshore environments, but continued effort is required to expand offshore wind to new markets and further reduce costs as the sector strives towards a ‘subsidy free’ future.

Innovation has been core to cost reduction efforts in offshore wind, with several studies indicating that technology advancements could cut the cost of offshore wind by ~33% by 2030 (KIC InnoEnergy, 2016) and ~60% by 2050 (TINA, 2015). An element of this reduction can be achieved through learning rates that come with increasing deployment, but there is also a critical need for targeted R&D activities to develop and de-risk cost-cutting innovations ready for commercial application. However, the high cost and risk associated with new technologies is a major barrier to commercialisation, necessitating government intervention to share the risk of undertaking R&D activities.

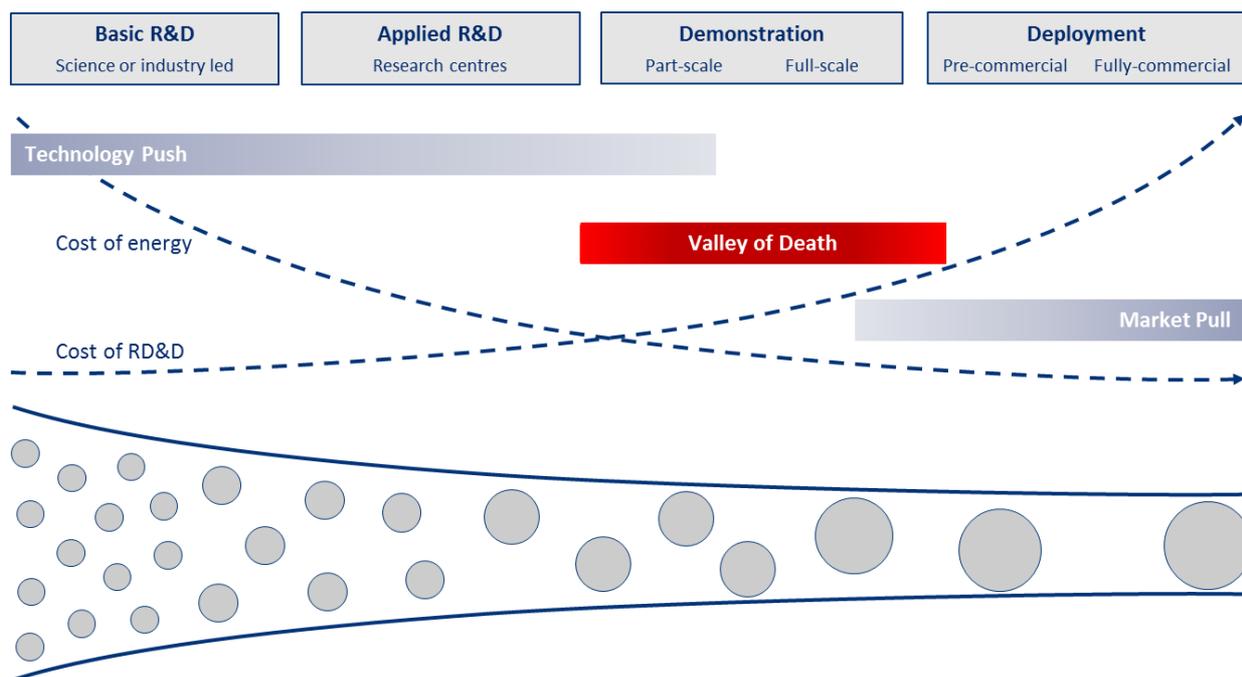
3.6.1 Technology commercialisation

Innovation of new technologies follows a progression from initial conception to basic and applied research, before part and full-scale demonstration to pave the way for commercial application. Typically, these are assessed by technology readiness levels. Each stage along the commercialisation pathway requires different levels of government intervention, reflecting a transition from technology push to market pull. Technology push for early stage technologies will consist of high government intervention through grant research funding, with increasing private contribution as technologies progress to higher readiness levels.

Basic R&D

At early stages of technology development, technology push R&D is dominant in supporting fundamental scientific research, often without a specific market application in mind. Small scale research of this kind is typically low cost but more extensive in the scope of research areas covered, providing grants to academic institutions to investigate the potential for a range of technology solutions, often more radical innovations with lower probability of market penetration.

Figure 14. Technology commercialisation R&D pathway



Source: Carbon Trust

Applied R&D

The most promising innovations are taken forward for further research, often through research programmes delivered by dedicated R&D centres. Here, the cost of R&D may increase but public expenditure can be supported by match-funding from the private sector to undertake more desk-based design modelling and laboratory testing of concepts. Collaborative R&D of this kind can help to share the cost and risk of R&D activities. A considerable amount of applied R&D may also be undertaken in-house by technology companies, particularly in areas where there is greater competition between suppliers (e.g. turbine manufacturers).

Demonstration

The final de-risking step before technologies can enter commercial projects is to demonstrate at part or full scale. The high cost of prototype demonstrations is a major barrier to commercialisation, often referred to as the valley of death. To bridge this valley of death, public investments will need to leverage a higher portion of private sector funding, which can be mandated in the terms for funding calls. In offshore wind, demonstration opportunities are further hindered by the availability of suitable test sites with low entry barriers, such as consent and grid availability. Integrating demonstrations within commercial deployments can be a more cost-effective means of demonstrating innovative technologies, but this requires appropriate policies and incentive mechanisms to prevent a barrier to implementation, particularly where competitive auctioning is present.

Deployment

Once demonstrated and proven in appropriate environmental conditions, technologies can be adopted in commercial projects. However, barriers still remain in integrating novel technologies into commercial projects due to the higher risk perception associated. Particularly where project financing is prevalent, higher perceived risk can result in less favourable lending rates, leading to higher cost of capital and higher cost projects. As such, developers may opt for proven lower risk technology options over more innovative alternatives, as the higher CAPEX may be wiped out by higher WACC. Undertaking comprehensive de-risking activities is therefore critical throughout the R&D process to lower the barriers to market uptake.

3.6.2 Policy tools

The technology advancements seen across the industry have been made possible by concerted research and development efforts to develop and de-risk new technology solutions. A range of government interventions have been implemented to stimulate R&D activity in offshore wind. Some countries, such as Germany, have favoured a greater emphasis on technology push research, with considerable public funding channelled towards academic institutions and research centres. In other countries, such as the UK, a greater emphasis has been applied to market pull initiatives that engage the private sector. Crucially, an appropriate balance of R&D activities is needed to ensure a steady stream of new technologies reaching the market.

A range of possible government interventions to support technology innovation are outlined below, from low to high technology readiness.

Research and development initiatives

- **Basic R&D:** Grant funding to academic institutions and dedicated research centres, typically associated with low TRL technologies. Limited private contribution.
 - **Examples:** DTU (Denmark); ECN (Netherlands); Fraunhofer IWES (Germany); NREL (USA)
- **Applied R&D:** Grant funding for mid-TRL technologies, often delivered with match funding from the private sector. The collaborative nature of these R&D initiatives lends them well to regional or international cooperation, often in the form of consortia addressing cross-industry challenges. But this can also involve direct grants to companies and innovators to develop technology solutions, as well as business incubation support to improve supplier route to market.
 - **Examples:** Carbon Trust Offshore Wind Accelerator (UK); TKI Wind op Zee (Netherlands); Horizon 2020 (EU); IEA-Wind (International)
- **Demonstration:** Funding for part- and full-scale technology demonstrations, at higher TRL levels. High cost requires large government grants, supplemented by private sector match-funding. It should be noted that funding for demonstrations needs to be supplemented with the availability of suitable test sites, which is often a major hurdle for single unit prototypes.
 - **Examples:** InnovateUK (UK); EUDP (Denmark); NEDO (Japan); DemoWind (EU)
- **Collaboration programmes & forums:** Across all levels of R&D, collaboration and information sharing between industry players is critical to maximising the impact of research activities. Commercial sensitivities can be a barrier to information sharing, but, if designed appropriately, collaborative research programmes and forums can provide mutual benefits which increase the pace of innovation.
 - **Examples:** IEA-Wind (International); ORE Catapult/Crown Estate SPARTA project (UK)⁴⁰

Test and demonstration facilities

- **Onshore component testing:** Onshore component testing is vital to validating performance and improving designs before offshore application. Several onshore test facilities have been set up across Europe with the help of public funding support.
 - **Examples:** Fraunhofer (Germany); ORE Catapult/NAREC (UK); LORC (Denmark); MARIN (Netherlands).

⁴⁰ SPARTA: System performance, Availability and Reliability Trend Analysis; a database for sharing anonymised offshore wind farm performance and maintenance data.

- **Onshore demonstration:** Full-scale onshore testing of turbine prototypes can mitigate some of the additional costs and risks of deploying offshore, provided the environmental conditions are suitably representative. Easy access can also enable closer monitoring and inspection for a range of R&D activities.
 - **Examples:** ECN Wieringerwerf (Netherlands); Levenmouth (UK)
- **Offshore – dedicated site:** An offshore test sites is designated for demonstration of novel technologies. These are typically high cost and must overcome barriers in securing consent, permits, and grid connection. However, these dedicated test sites can be used effectively to increase the innovative elements of the installation, due to the limited conflict with commercial activities.
 - **Examples:** Alpha Ventus (Germany; see Box 29); Blyth (UK); European Offshore Wind Deployment Centre (UK); Nissum Bredning (Denmark)
- **Offshore – adjacent to commercial wind farms:** Test sites designated next to commercial projects can leverage existing site permits and grid connection to remove barriers to entry.
 - **Examples:** Gunfleet Sands III (UK); Borselee V (Netherlands)
- **Offshore – integrated within commercial wind farms:** A select number of units in the wind farm are designated for innovative technology demonstrations.
 - **Examples:** Borkum Riffgrund (Germany); Belwind (Belgium)

Remuneration incentives

- **Enhanced subsidy support:** As a means of bridging the gap from prototype demonstration to widespread commercial application, higher subsidies can be awarded to particularly novel technologies for small scale commercial projects. Floating wind, for example, currently requires higher subsidy support for pre-commercial projects before it can compete on an equal commercial basis with fixed-bottom offshore wind.
 - **Examples:** Enhanced ROCs for innovative foundation technologies (Scotland); Pilot floating offshore wind tender (France)
- **Innovation requirements:** Similar to local content provisions, governments can impose requirements to include a certain amount of technology innovation in projects. This high interventionist approach is difficult to assess and apply consistently, usually conflicting with cost reduction efforts. As such, this approach is rarely compatible with competitive auction-based systems, where separate support mechanisms will be required (i.e. grant or enhanced subsidy). Minimum innovation requirements are more likely to be effective in dedicated demonstration projects.
 - **Example:** Eneco Luchterduinen/Q10 (Netherlands); US Department of Energy demonstration projects.

3.6.3 Lessons learned

Strategic identification and prioritisation of technology innovation needs can focus R&D efforts

Given the high cost of undertaking R&D activities, it is important that governments channel funding towards activities that will provide greatest impact to the industry, as well as maximising benefit for domestic companies. In this regard, governments can align innovation funding with industrial strategy, identifying and prioritising areas of specialisation to support companies with the potential to achieve a competitive advantage in the global marketplace (see Box 27).



Box 27: UK Technology Innovation Needs Assessment

UK R&D activity has been underpinned by strategic identification and prioritisation of R&D needs. Commissioned by the Low Carbon Innovation Coordination Group (LCICG), a network of UK R&D bodies, and delivered by the Carbon Trust, a series of Technology Innovation Needs Assessments (TINAs) have been undertaken across a range of low carbon technologies, including offshore wind. The assessments have used a range of key metrics, including impact on cost of energy, domestic value creation, and export value creation, to highlight focus technology areas for R&D activity across its member organisations.

Creating close ties between academic research centres and industry can maximise market penetration of novel technologies

Achieving market penetration is a common challenge for technology-push academic research. A lack of convergence between R&D activities in academia and industry can limit the potential to convert research into commercial application. Closing the gap by creating strong links between industry and academic research centres can mitigate this risk, ensuring that technologies are developed to respond to industry need and that industry players are aware of cutting edge research within research centres that can be applied in future offshore wind projects. This low TRL research and development is vital to achieving long-term cost reduction goals and evaluating the potential of more radical technology innovations. An example of forging such links includes DTU in Denmark, which has established strong links with Danish industry players such as DONG Energy, Siemens, and Vestas.

Collaborative R&D programmes can maximise the impact of public and private funding

Another effective means of generating greater market pull has been seen through the creation of collaborative R&D initiatives and joint industry projects. Collaboration enables the costs and risks of R&D activities to be shared between industry players, leveraging public and private funding to undertake targeted R&D addressing common industry challenges. Having industry players steer R&D activities can ensure that investment is focussed on the most pressing challenges and increases the probability that technology solutions will find application in the market.



Box 28: Carbon Trust Offshore Wind Accelerator

The Offshore Wind Accelerator (OWA) is a collaborative R&D programme between the UK and Scottish Governments and 9 of Europe’s leading offshore wind developers. Set up in 2008, the programme has delivered over 100 R&D projects with a cumulative value of over \$100m (equiv. €95m). Research priorities are set by the industry partners, maximising the impact of both public and private funding. The programme has supported a number of offshore wind innovations, providing funding support to commercialise cost-cutting technology solutions and connecting innovators with industry end-users.



Source: Carbon Trust

Involving financial institutions and lending advisers early in the R&D process can mitigate high risk perception of new technologies

One of the biggest barriers to bringing new technology innovations into commercial projects is the added perceived risk compared to existing solutions with a longer track record. The impact of higher perceived risk manifests itself in less favourable financing terms and higher costs of capital, which could mitigate any CAPEX or OPEX savings from the new technology solution. Closer involvement of financial institutions and lending advisers in R&D activities can ensure that risks and benefits of innovative technologies are fully understood and that R&D de-risking activities are designed accordingly. Particularly with the transition to competitive auctions in many countries, de-risking the uptake of cost-cutting innovation should be a priority for industry.

Policies should be designed to enable integration of technology demonstrations in commercial projects

Achieving full-scale demonstration in a representative offshore environment is a critical step in the de-risking process, but one of the most difficult to achieve. The high cost and limited access to suitable permitted sites makes this a major barrier to implementation. Several dedicated offshore wind test sites have been developed with the help of public funding, demonstrating new technologies and serving as hubs centres for ongoing testing and monitoring (e.g. Alpha Ventus, Germany; see Box 29).



Box 29: Alpha Ventus & RAVE

The Alpha Ventus test site, installed in 2010, was Germany's first offshore wind farm, consisting of 12 innovative 5 MW Areva (x6) and Senvion (x6) turbines supported by novel jacket and tripod foundations. The €250m project has served as the basis for considerable R&D activity, including the RAVE initiative, a ~€50m research programme with over 50 partners delivering over 40 R&D projects. Experience gained in constructing and operating the wind farm has been fundamental in preparing for the large scale roll out of offshore wind in Germany and wider European market.



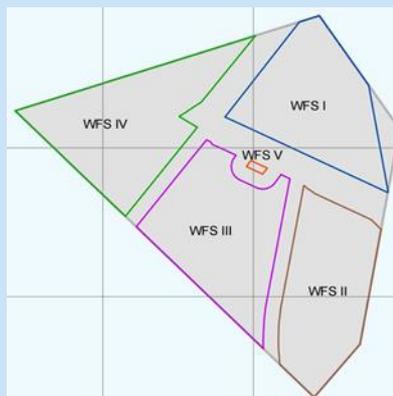
Source: Sean Gallup/Getty Images

However, while dedicated test sites are effective for R&D purposes, they are more expensive and require considerable public funding. A more cost-effective means of enabling technology demonstrations is to integrate within or alongside commercial wind farms. This approach results in easier and lower cost permitting and grid connection and also ensures that technology demonstrates are commercially-driven and aligned with industry priorities. Examples include the demonstration of a suction bucket jacket foundation as part of the Borkum Riffgrund I wind farm in Germany and the Gunfleet Sands III extension project in the UK, consisting of two 6 MW Siemens turbines. However, with the transition to competitive auctions putting increasing pressure on price to win contracts, for future demonstrations there will need to be a suitable policy framework and incentive mechanism to cover the higher costs and risks involved (e.g. enhanced remuneration support).



Box 30: Borssele V test site

As part of the Dutch offshore wind roadmap to 2023, a site for 20 MW installed capacity has been made available by RVO for up to two turbine demonstrations, which will connect to the Beta substation for Borssele III and IV. The provision of consent and grid connection reduces development cost and risk, and the close proximity to commercial projects will enable easier operation and maintenance. The incentive mechanism for the project has yet to be determined, but is expected to include an enhanced subsidy on top of the SDE+ tariff determined for Borssele site III. The project will be subject to competitive tender, but evaluated on quality of technology innovation, as opposed to price. The evaluation criteria will also include a local content requirement to maximise benefits for Dutch technology companies.



Source: RVO

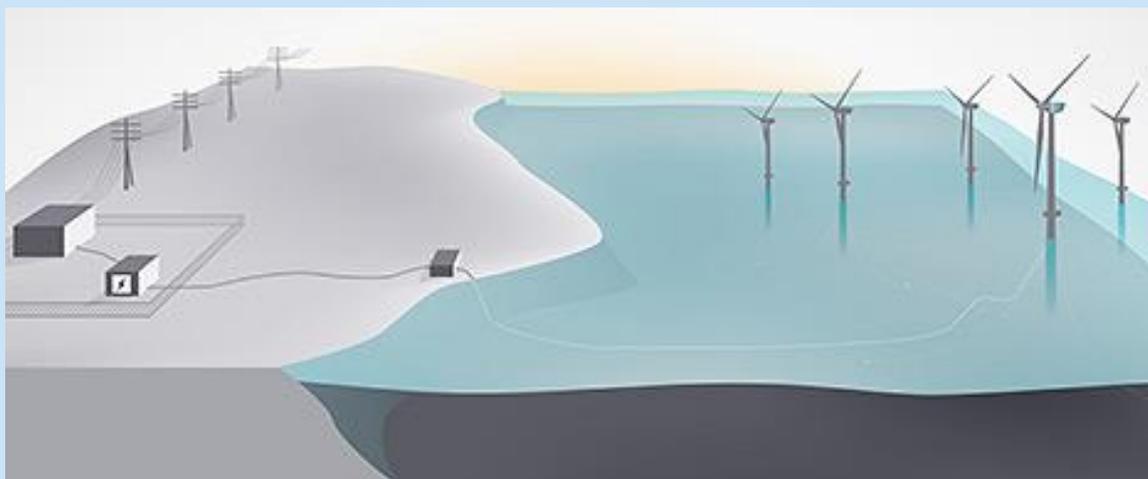
A balance of innovation support should be maintained across technology readiness levels

While a focus on mid- to high-TRL solutions through market-pull initiatives is likely to deliver greater immediate impact in the near term, policy makers should ensure that public funding is still channelled towards low-TRL basic and applied R&D activities. Even as the industry matures, offshore wind will need to continue innovating and developing new, sometimes radical, solutions to deliver cost reduction and open new markets for the sector. Innovation activity may also need to evolve in response to changing electricity markets, including greater interconnection and integrating system balancing technologies within wind farms (e.g. energy storage; see Box 31).



Box 31: Hywind-Batwind Pilot Project

Statoil are currently developing a highly innovative project in Scotland which will consist of the world’s first pre-commercial array of floating wind turbines and the demonstration of a new battery storage solution. The 30 MW Hywind Pilot Park, comprising five 6 MW Siemens turbines supported by floating spar-buoy platforms, will be connected to a 1 MWh lithium battery, highlighting the opportunities for wind power and energy storage to offer an integrated solution with system benefits.



Source: Statoil

4 INDUSTRY STRUCTURES

- The industry has developed in recent years and may be entering a market maturation phase in key established markets such as the UK and Germany.
- The market has been comprised of two distinct models: the utility and independent power producer developer (IPP) models.
- Developer models have evolved, with growing use of project finance by utility developers, and a trend towards development consortia.
- Predictions of capital constraints have not been borne out, due to slower pace of development and increasing trust by funders in the industry's capabilities.
- Emerging markets have significant supply chain capabilities due to pre-existing onshore wind and oil & gas industries. However, lack of vessels for WTG lifting and O&M servicing could present as bottlenecks for non-European markets.

A growing body of evidence suggests that the offshore wind industry in the established markets of Northern Europe has matured in recent years. The industry has moved from innovation (1990 to 2001), adaptation (2002 to 2008), to market stabilization (2009 to 2015)^{41,42,43}. The market stabilisation phase is marked by an increase in project size; the development of dedicated manufacturing facilities and a supply chain distinguishing itself from the oil & gas and onshore wind industries. Evidence from the stakeholder interviews suggest further developments through the market stabilisation phase, suggesting that the industry may be moving into a 'market maturation' phase:

- Steep cost reduction evident in several European countries.
- Several European markets have become commoditised, with financial investors, commonwealth funds and pension funds now investing in operating assets, allowing utilities to recycle capital to new projects.
- Perceived risks from the investor and finance community have been reduced due to growing confidence in the ability of developers and the supply chain.
- Project margins have reduced over the last five years due to increased confidence in the industry and perceived reduction of residual risk levels.
- Consolidation of industry developers, particularly in the UK where significant exits have left fewer players in the market.

The following sections identify the dominant industry structures and how they have changed in recent years, through discussion of:

- **Project Developers:** companies whose business model is to develop a project through one or more phases of an offshore wind farm.
- **Investor Community:** companies who provide capital for offshore wind projects in the form of equity or debt.
- **Supply chain:** companies involved in the manufacturer and installation of offshore wind farms.

⁴¹ Dedecca et al. 2016. *Market strategies for offshore wind in Europe: A development and diffusion perspective*. Renewable and Sustainable Energy Reviews. available at: <http://www.sciencedirect.com/science/article/pii/S1364032116304233>

⁴² Higgins and Foley. 2014. *The evolution of offshore wind power in the United Kingdom*. Renewable and Sustainable Energy Reviews. available at: <http://www.sciencedirect.com/science/article/pii/S1364032114003839>

⁴³ Kern et al. 2014. *From laggard to leader: Explaining offshore wind developments in the UK*. SPRU Working Paper. available at: http://sro.sussex.ac.uk/48296/1/2014_02_SWPS_Kern_et.al.pdf

4.1 PROJECT DEVELOPERS

Utility vs. independent power producers (IPP)

There are two broad categories of developer model: the utility-developer and IPP-developer (see Table 14). Historically, utility-developers relied mainly on balance sheet financing with less third party scrutiny which enabled them to adopt higher risk approaches, with more contracts and more aggressive scheduling. In contrast, IPP-developers tended to adopt risk adverse strategies, with a smaller number of construction contracts, conservative scheduling and technology choices to meet requirements of debt providers.

Table 14: Contrasting development strategies in offshore wind

Development aspect	Utility-Developer Model	IPP-Developer Model
Size of development team	Relatively large, with the potential for hundreds of staff to be working on projects. Large teams create communications challenges	Relatively small, typically using tens of staff. Typically have better communication but struggle with resource when material issues occur
Risk tolerance	Relatively high and mitigated through use of a large owner management team	Relatively low, driven by external financing requirements
Scheduling	Often attempt to perform more tasks either in parallel or with limited float ⁴⁴ between packages to attempt to obtain a shorter construction timeframe	Typically a conservative schedule with greater float between contractual packages
Level of innovation	Typically tolerant of new technologies which may lead to cost reduction or performance enhancement	Preference for more proven technology to reduce risk
Number of construction contracts	Relatively large, often tens of main contracts used	Typically two to six
Construction contract terms	Typically fixed price contracts, backed by strong warranties, guarantees and damages used, to pass the majority of construction risk to contractors. Utilities may be more willing to accept certain contractual risks such as weather downtime sharing.	Typically fixed price contracts, backed by strong warranties, guarantees and damages used, to pass the majority of construction risk to contractors. More conservative contracting approaches, with limited sources of cost over-runs preferred
O&M strategy	Often looking to take over O&M within 2 to 5 years and build an O&M business	In recent years have been able to access long term O&M contracts with turbine suppliers and have typically procured 15 year terms.
O&M contract terms	Utilities provide fixed or variable cost O&M agreements after expiry of WTG O&M agreement	Fixed price, availability warranty backed contracts with WTG suppliers' standard

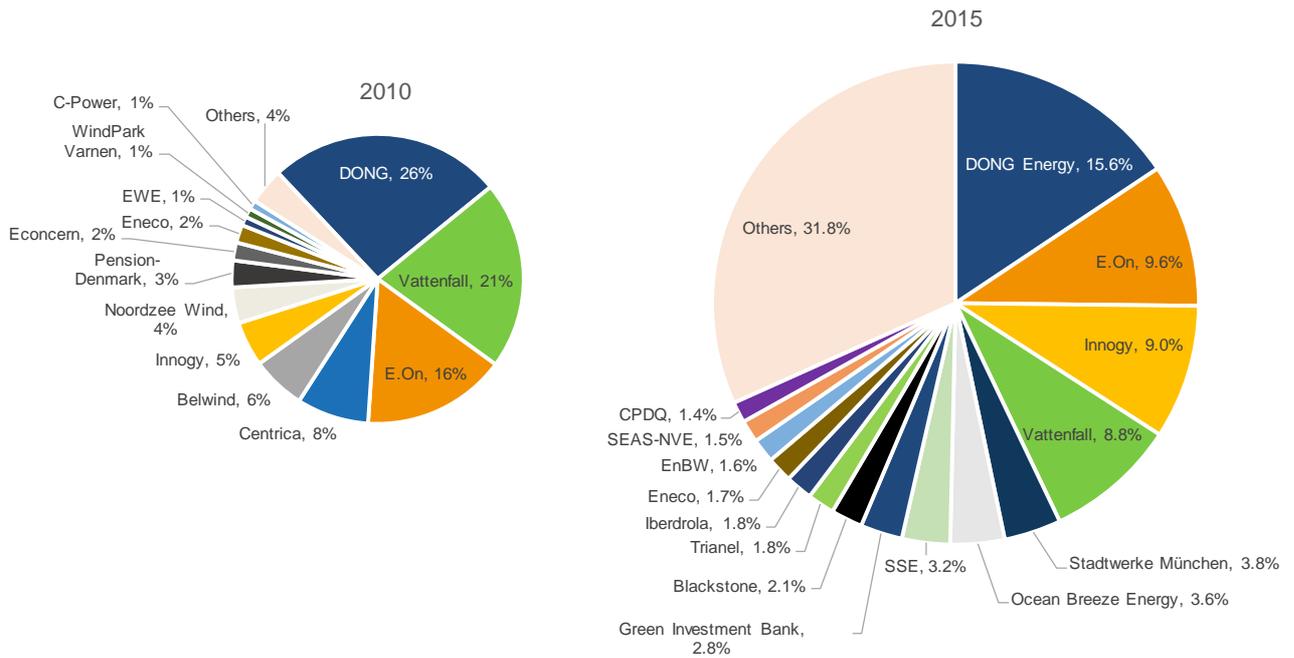
Source: Mott MacDonald, based on stakeholder interviews and project experience

⁴⁴ A float is a buffer between sequential works to have contingency for delays (to cover weather risk, technical, other delays)

4.1.1 Key players

The ownership of cumulative offshore wind installed capacity is displayed in Figure 15. The top five players by ownership assume technical roles, hence can be classified as developers and have a cumulative market share of 46.8%. Major shareholders Green Investment Bank (GIB), Blackstone and Caisse de dépôt et placement du Québec (CPDQ) by contrast do not assume any key technical roles in the projects. The large share of “other” demonstrates that ownership is spread among a large number of stakeholders and is also a reflection of equity divestment once projects are operational.

Figure 15: Cumulative installed capacity by developer, 2010 and 2015



Source: WindEurope

The majority of developers are utilities that typically have a thermal power generation, power distribution and transmission background with no previous offshore experience. IPP-developers typically have an onshore wind and/or broader renewables background. However, individuals within the developers’ project teams can have much more diverse backgrounds than the corporate CV of the Developer.

While utility-developers initially focussed on their domestic market, all major developers are now active in several country markets across Europe. This has led to similar developer structures across Europe. The only exception is France, where some of the successful bidders have no previous offshore wind experience and have entered the market as consortia partners with more experienced developers. This may be partly attributable to the use of domestic content by France as a key evaluation criteria in Rounds 1 and 2. Generally, the industry has seen a consolidation of the market leaving fewer players than five years ago, including the announced market exit by utility-developers Statkraft and Centrica.

Developer-supply chain collaboration

Original Equipment Manufacturers (OEMs) only rarely take on an investor or even developer role. Siemens and DEME (a marine contractor) and most recently Van Oord and MHI Vestas are notable exceptions. Likewise, the developer's involvement within the supply chain is limited and typically includes shareholding in logistics suppliers or acquisition of vessels, for example, Dong's shareholding in logistics provider A2SEA. Innogy had previously acquired jack-up vessels but decided to sell them during 2013 and 2015. With the introduction of auctions, the market has seen greater involvement of the supply chain on the developer side and the industry is looking to establish a closer liaison between developers and the supply chain to collaborate and achieve further cost reductions.

Developer profiles

Key utilities and IPP developers are discussed further in the text boxes below.



Installed capacity: 1,964 MW

DONG Energy was established in 2006 by the merger of six Danish energy companies: Dong, Elsam, Energi E2, Nesa, Københavns Energi and Frederiksberg Forsyning. At this time its predecessors had a sizable portfolio of operating offshore wind farms, including the world's first offshore wind farm Vindeby that entered into operation in 1991 and is undergoing decommissioning at the date of this report. Elsam had successfully constructed Horns Rev 1 that was completed in 2002, while the Danish energy company Energi E2 operated Nysted Offshore Wind Farm that was completed in 2003. Dong also had a large and well-developed pipeline of offshore wind projects.

Today, DONG Energy is the largest offshore wind developer in the world, with shareholding in 18 operating offshore wind farms totalling a capacity of 3 GW by November 2016. Dong has also been a successful bidder under the Dutch auction round for Borssele I & II.

DONG Energy is active across Europe, including the Denmark, UK, Netherlands, Germany and France, but also provided a substantial boost to the US offshore wind industry when it bought into a 1 GW project in development in Massachusetts. DONG Energy recently established presence in Chinese Taipei too and, as such, is covering all key offshore wind markets to date.

DONG Energy's business model follows that of a typical utility developer whereby construction is financed on balance sheet. DONG Energy takes over responsibility for WTG operation and maintenance after the end of the warranty period and divests equity typically when a project enters into operation, albeit divestment may be earlier in the project lifecycle depending on the risk appetite of the investor.



Installed capacity: 1,057 MW

Innogy, formally a subsidiary of German utility RWE, has recently been through a successful IPO process and now focuses its activities in three core areas: renewables, gas & electricity networks and retail. Innogy entered the offshore wind market in 2003 with the construction of the first commercial offshore wind farm in the U.K. The utility has the 3rd largest offshore wind capacity in the world, owning 9% of operational capacity at the end of 2015, according to Wind Europe; four projects in the UK and one in Germany and one in Belgium. Two more projects are under construction in 2016 in the UK and Germany. Further projects are under construction in the UK and Germany with more being developed and would need to succeed in auction rounds to obtain revenue incentives and proceed with construction.

Innogy was the first owner to purchase large vessels to assist in installation and maintenance of its wind farms. However, one vessel was sold and one chartered for five years in 2015. Innogy stated this was because construction was no longer part of its core business activities. This vessel ownership approach has not been replicated by any other wind farm developers. To date Innogy has not yet been successful in bidding under the recent auction regimes.



Installed capacity: 1,049 MW

Eon is a German utility which owned 9.6% of operational European capacity at the end of 2015, including eight offshore wind farms in the UK, Germany, Sweden and Denmark. Eon entered the offshore wind market with the first offshore wind farm in German waters, Alpha Ventus, Robin Rigg in the UK and Rodsand 2 in Denmark. For the majority of its operating portfolio, Eon is the sole shareholder. However, for its larger projects, including London Array, Eon has worked in consortia with other developers.

Two projects are under construction in the UK and Germany in 2016 and one project is under development and obtained construction permit in Germany. To date, Eon has participated in auctions but not yet been successful with a bid. While the company is headquartered in Germany it has been more active in the UK to date. In 2011, Eon signed a six-year vessel charter agreement for offshore wind construction.

As of January 2016, Eon’s fossil power business is entirely separated from its renewables business to focus on renewables and energy efficiency services.



Installed capacity: 902 MW

To date, Vattenfall has secured the highest cumulative capacity of the recently introduced auctions in Europe of which all is located in Denmark and with tariff levels well below successful auctions in other countries. All Vattenfall auction wins have been achieved without development partners and it remains to be seen whether Vattenfall is going to seek partners to proceed with the construction of these projects. Vattenfall had been initially consortia partner with Iberdrola for the successful bid on East Anglia offshore wind farm, but exited from the project.

With its pipeline, the success of Vattenfall in delivering the auctioned projects will be pivotal for the wider confidence among investors and lenders that such material cost reductions can be achieved to make project viable with low tariff levels.

Key emerging utility developers

Tenders that have been awarded under auction regimes between 2012 and 2016 demonstrate that the majority of the market share is assumed by established developers. Some new entrants have been driven by local content requirements in France. As no project under auctions has been constructed as of quarter 1 of 2017, developer roles and split of responsibilities within a bidder consortia are not always evident and will only become more evident as projects progress in development and construction.



Iberdrola is a Spanish utility and acquired UK-utility Scottish Power Renewables in 2007. To date Iberdrola has been the 11th largest developer with one operational offshore wind farm in the UK that is jointly owned with Dong. One wind farm is under construction in Germany and wholly owned by Iberdrola. In terms of the market share of awarded bids under auctions, Iberdrola is ranked second, ahead of Dong, with its successful bid for East Anglia One and the first French offshore round under which Iberdrola participated in a bidder consortium.



EDF is a French power utility. EDF owns Teeside, the 62 MW operational wind farm in the UK, is developing the 41.5 MW Blyth farm in the UK, and is part of the successful bidder consortia of three round one projects of the French offshore wind tender that are currently under development (Saint-Nazaire, Courseulles-sur-Mer, and Fécamp).



Enbridge is a Canadian power utility and entered the offshore wind market in 2015 with the acquisition of shares in one UK offshore wind project that is under construction in 2016. Enbridge is in the process of acquiring shares in a German offshore wind project that is due to enter into construction in 2017 and has acquired shares in French offshore wind farms that have been awarded tender in the first round of French offshore wind tenders.



Engie (former Gaz de France Suez) is a French gas utility that to date does not own operational assets or those under construction. Engie was successful as a partner of a consortium on two projects in the second round of the French offshore wind tenders. Participation in tenders outside France is not known.



Energias de Portugal Renováveis (EDPR) is a Portuguese power utility that similarly to Engie does not have previous offshore wind experience and was a successful consortium bidder alongside Engie in the second round of French offshore wind tenders. Participation in tenders outside France is not known.



Shell, the Dutch oil and gas company, has re-entered the offshore wind industry after it's exit in 2008. The company was part of an unsuccessful consortium (including Eneco) for Borssele 1&2, but was successful in a consortium with Eneco and Mitsubishi/DGE in the 700 MW Borselle III and IV tenders at €54/MWh.

Key IPP developers

IPP developers by their nature are typically smaller sized organisations limited by their financial capabilities and which often sell projects prior to entering into construction. As such, these are not ranked among the top developers in terms of market share. Nevertheless, they can be equally successful in developing and/or delivering projects. This section sets out some of the key IPP developers, acknowledging that there are numerous others.



Parkwind is a Belgian-based developer responsible for the Belwind, Northwind and Nobelwind offshore wind farms financed in 2009, 2012 and 2015 respectively. The company was formed after the insolvency of Ecoventures B. V., with staff responsible for early offshore wind developments such as Princess Amalia in the Netherlands. Over time the company has grown from a small entity with few employees, reliant on contractors and consultants to deliver its services, to one of the largest independent developers in Europe, with almost 100 staff.



WPD is a successful onshore and offshore wind developer and operator based in Germany. Its first three offshore wind projects were developed to the consenting phase before being sold to utility EnBW. Following this success, the company developed German offshore wind project Butendiek (in operation) and acquired Nordegrunde from Energiekontor (in construction). WPD has been successful as consortium partner of the French offshore wind auction and owns a project at an early development stage in Sweden, albeit there is no certainty of the regulatory regime. WPD has competed for auctions (for Kriegers Flak and the nearshore offshore wind tender) in Denmark as a consortia partner but has been unsuccessful to date.



Deepwater Wind was created in 2008 specifically for the development of offshore wind projects in US waters. Deepwater is owned primarily by affiliates of D.E. Shaw & Co, which has invested in a number of energy projects. The Deepwater’s Block Island Wind Farm is the first offshore wind project in the United States and it declared COD December 2016.

4.1.2 Success of developer models

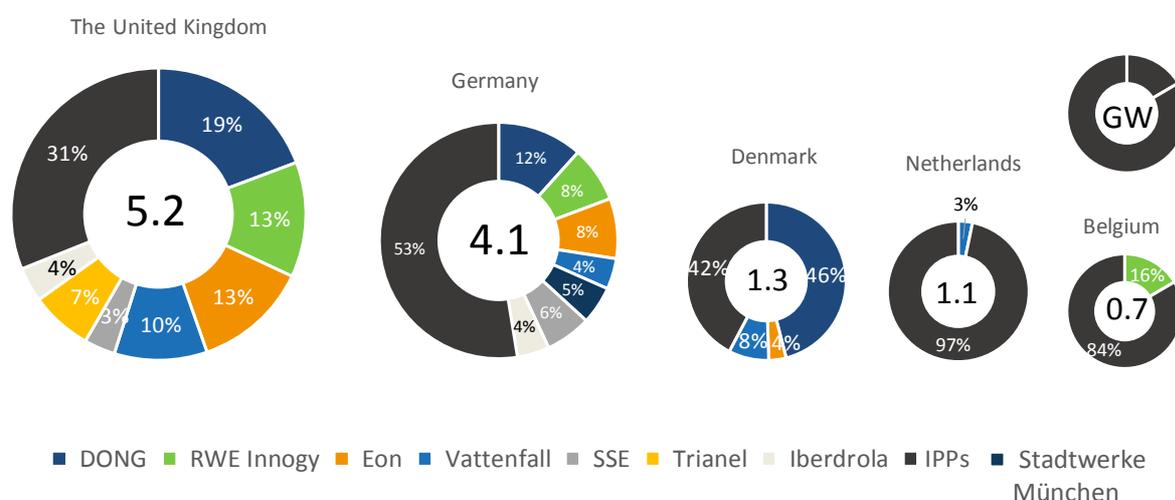
Market share of utility and IPP developers

Acknowledging that the market share can only provide limited indication of success of developer models, the market share and drivers of the biggest utility developers for operating projects in the key European offshore wind markets were assessed. The analysis shows that the market share of the biggest utility developers varies materially between the different country markets and that both utility and IPP developers have a place in the market (see Figure 16). In Denmark and the UK, the big utilities jointly own more than half of the operating capacity. In the Netherlands and Belgium, the market has been dominated by IPP-developers. In Germany, there is more of a balance between utility-developers and IPP-developers. Notable in the German offshore wind market is the participation of municipality utilities such as Stadtwerke Muenchen and Trianel, which is a consortium of 56 municipality utilities from Germany, the Netherlands, Austria and Switzerland. Trianel’s business model demonstrates the appetite of smaller utilities to participate in the market.

Drivers for the high utility share in the UK can include the pre-selection of sites using an auction mechanism for exclusivity agreements that required a minimum credit rating and a smaller domestic onshore wind IPP market which is typically the background of IPPs in the offshore wind market. With its quota obligation, UK-based utilities had an enhanced incentive to establish renewable technologies within their portfolio.

In Belgium and the Netherlands, IPPs have been successful in attracting funding from lenders relatively early in the market and built on that success. The smaller country market volume may also be less attractive to international utilities than larger volume markets with established presence.

Figure 16: Market share of utility-developers in operating projects

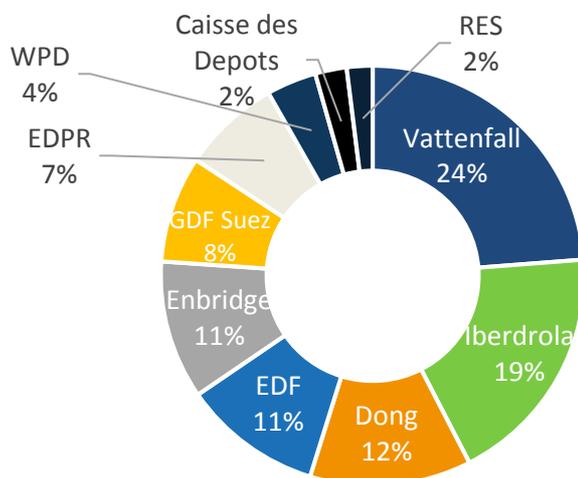


Source: Mott MacDonald analysis, based on Wind Europe, 2016

As the European offshore wind market is in the process of transitioning to auction regimes, the industry track record is still limited and, as such, a potential impact on the market share of developer models is yet to be validated. To date, 13 projects have been awarded contracts under a competitive auction regime of which one developed by an IPP has been terminated (Nearth Na Gaoithe, UK). The terminated contract has been excluded for this analysis. The remaining 12 projects represent a total capacity of 5,680 MW awarded via competitive auctions to date. None of the awarded projects have proceeded to construction at the date of this report.

Of the European auctions, 92% of awarded project capacity was won owned by utility-developers (see Figure 17). The only IPP-developers that were successful in auctions to date, and remain shareholders in the projects, are RES and WPD, which were successful in French auctions through bidding in consortia with utility developers. This early auction structure appears to indicate that the emerging regime favours utility-developers and that IPP-developers will rely on collaboration with utility developers.

Figure 17: Developer market share based on awarded bids under auction regimes



Source: Mott MacDonald analysis based on published auction results covering European offshore wind tender awards between 2012 and 11/2016 in the UK, France, Denmark and Netherlands

The increasing market share of utility-developers is partially driven by the increase in project sizes, hence the associated investment volume and requirement for placing a substantial bid bond. Increased project sizes have also led to utilities no longer being able and/or willing to wholly assume the construction risk of a project, which is reflected in the consortia that have been formed between the major utilities. Among the utilities, the strategies vary in when equity partners are brought in, i.e. prior to or after bid submission.

Except for Engie and Caisse des Depots, all developers that were successful in auctions are developers with previous offshore wind experience under quota and feed-in tariff regimes.

Key success factors

Experience in the market has shown that both utilities and IPPs have established successful business models and can operate in and adjust to different policy frameworks provided the risk-reward balance of a policy framework is acceptable to developers.

Our analysis, stakeholder interviews and literature review confirm that there have been successes for both utility and IPP developers. Key differentiators of successful from less successful developers are not the developer model or policy framework design but include:

- Financial capabilities;
- Technical capabilities and experience of developer team;
- Robust planning with fall-back plans;
- Robust project agreements; and
- Appointment of experienced contractors.

With an increase of project size, investment volume and introduction of auctions and bid bonds, sound financial capabilities are key to a developers' success, as was confirmed with stakeholder interviews. Financial and technical capabilities may or may not be delivered by the same entity within a developer consortium.

Technical capabilities of the developer team have been proven to be pivotal to the success of a project. Whilst risks have been identified across the industry, the capability of effectively managing and mitigating risks varies between developers and is a key determinant for success. Experience has shown that increasing the size of developer teams does not always result in better results as it tends to compartmentalise teams and introduce interfaces that are more challenging to be overseen.

With a trend towards developer consortia, it will be key that the developers' project management teams are equipped with sufficient authority to act swiftly. Successful developer teams tend to have established fall back plans early in the process which enables them to deal with risks effectively as and when they arise.

With a greater number of project agreements, the interface risk is higher. However, experience in the industry to date has shown that there is no direct relationship between developer success, project cost and the number of contracts. The driver for success is less to do with the number of contracts, but rather the detail of the terms and conditions under each contract and how interface risks are managed. Contracts of successful projects tend to be clearer in their risk allocation and interfaces, as such leaving less potential for disputes and cost overrun. Contract suites of successful projects include a robust incentive and penalty regime that focusses on mitigation of key developer risks. With the provision of schedule float between the works under different contracts interface risks can be managed effectively.

Likewise, experienced contractors are a key success factor but it is crucial that they are experienced in the assigned scope of work. Additionally, familiarity between different (consortia) contractors and/or between the contractor and the developer can be a supporting factor for successful delivery.

Factors of failure

Examples in the early days of the offshore wind industry have shown that some contractors pre-maturely took on EPC contractor roles for work packages that were not always successfully delivered. Lower number of contracts in the beginning of the industry did not result in lower contingency expenditure by developer, as contractor's were not yet ready to manage EPC contractor risk and owners effectively provided support. Contrary, some IPP-developers that rely on project finance, were not able to attract debt funding due a contracting strategies using too many construction contracts and inadequate risk mitigation.

4.1.3 Recent trends in the developer models

Table 15: Trends in developer strategies

Developer	Utility-Developer	IPP-Developer
Development	<p>Consortia set up with other utilities and/or IPP developers to share development risk pre-construction/pre-bid award and manage risks of increasing project sizes, hence investment volumes. Increasing pressures for cost reduction led to the adoption of innovative technologies with shorter track records e.g. larger WTGs.</p>	<p>Teams growing in size and experience. Finance parties more willing to accept technologies with shorter track records e.g. larger WTGs. New entrants (such as marine contractors and oil and gas companies) participating in recent auctions in development roles. Option to partner with utilities as bidder consortium under auction regimes (e.g. WPD and RES in French offshore tenders).</p>
Procurement	<p>Utilities are tending to use fewer contracts, similar to the IPPs, reflecting greater levels of trust in the supply chain. Some utilities have offered EPC contracts between the utility and Special Purpose Vehicle (SPV) to attract pre-construction finance. Underwriting below these EPC contracts (where offered). Projects with high levels of construction risk (e.g. a large number of contracts and no EPC arrangements) have typically had to offer some level of protection at shareholder level to attract pre-construction finance.</p>	<p>Use of multi-contract strategy, typically 4 – 6, becoming acceptable and investors becoming comfortable with the SPV taking more risk within the contractual suite (e.g. weather risk sharing). Move to auction systems may require developers to take more construction risk to remain competitive.</p>
Financing	<p>Costs associated with larger project sizes are requiring external equity and in some cases debt. Wide variety of financing options being seen, with associated impacts on development style:</p> <ul style="list-style-type: none"> • Pre-construction finance becoming available from financial institutions with higher level of construction risk appetite. • Project-finance being used as alternative to balance-sheet financing. • Recycling capital at the date operations commences becoming easier, although investors typically require some insulation from O&M cost downsides. 	<p>Due to lack of capital at the independent developer level, equity and debt financing typically required before construction commences.</p>
Operations	<p>Utilities still typically take over O&M after 2 to 5 years but are becoming willing to offer more robust contractual terms to the SPV, e.g. relatively fixed price long term availability warranty backed O&M contracts, to attract investment. Utilities with large portfolios in a certain area e.g. around Barrow-in-Furness, UK, setting up O&M hubs to serve multiple wind farms. Larger scope/packages for balance of plant O&M.</p>	<p>Financial investors have preferred the lower risk option of a long-term WTG O&M contract although it is unclear whether the increased cost of these contracts will allow developers to remain competitive in upcoming auctions without reducing contract term. While earlier projects often contracted balance of plant O&M to a single institution, developers are becoming experienced at delivering these services and investors comfortable taking associated risks.</p>

Source: Mott MacDonald

4.2 INVESTOR AND FINANCE COMMUNITY

Investors and lender provide a key service to the industry, providing funding to a project throughout its lifecycle. This section describes the key players and recent trends in the sector.

4.2.1 Key players

Prior to and during construction utility-developers and/or IPP-developers account for most equity shareholding. Typically, utility-developers divest equity once a project is operational, however, this can vary depending on the risk appetite of the investor. Besides utilities, key equity shareholders include investment, equity and infrastructure funds, pension funds (primarily Danish) and general trading corporations (see Table 16). To a minor degree the supply chain OEMs may acquire minority shares. Such involvement may be driven to introduce new technologies. Most recently the offshore wind market attracted corporations such as Lego, whose involvement besides the return on investment is driven by meeting its own sustainability and green credential targets in terms of the carbon footprint and offset of its business activities⁴⁵.

Debt is typically provided by a mix of institutional lenders, development banks and commercial banks. Notable is the interest of Japanese funders in the European offshore wind market which is likely to be driven in part by the outlook for offshore wind developments in their domestic market. Most other lenders are European.

Table 16: Key funders in addition to developers

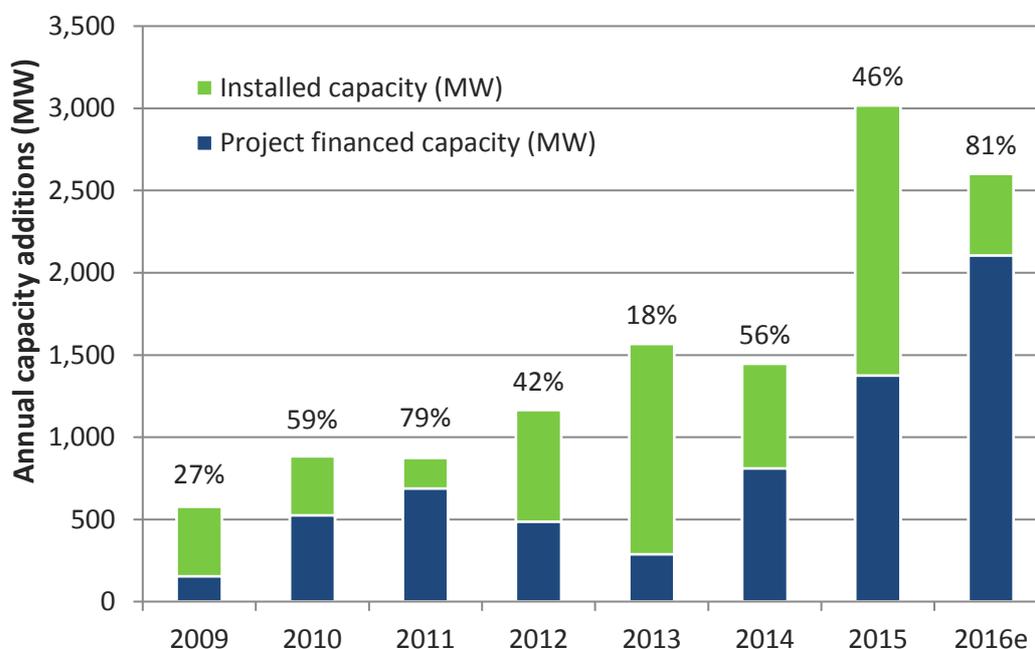
Group	Key players
Owners / equity providers	
Investments / equity / infrastructure funds, institutional investors	Copenhagen Infrastructure Partners, Global Infrastructure Partners, Infrared Capital Partners, Black Rock, Masdar, PGGM, Blackstone, Macquarie, Partners Group, Caisse de dépôt et placement du Québec (CPDQ)
Pension funds	PKA, Pension Denmark, Industriens Pension
OEMs	Siemens, GE, Van Oord, Deme
Corporations with sustainability targets	Lego
General trading corporations	China Three Gorges, Marubeni, Sumitomo
Debt provider / Lenders (may or may not also provide equity)	
Institutional lenders / development banks / export credit agencies	EIB, KfW IPEX, GIB, Development Bank of Japan, Eksport Kredit Fonden (the Danish export credit agency), GIEK (the Norwegian export credit agency),
Commercial banks	Commerzbank, BNP Paribas, Rabobank, Dexia, LBBW, SEB, Siemens Bank, Societe Generale, Bank of Tokyo-Mitsubishi, ING, Sumitomo Mitsui Banking Corporation, ScoGen, Keybank

⁴⁵ Lego corporate website, available at: <https://www.lego.com/en-gb/aboutus/news-room/2015/october/wind-farm-inauguration>

4.2.2 Key trends

A majority of early offshore wind projects were funded on balance sheet, reflecting the preferences of early investors (i.e. utility-developers) rather than a lack of bank appetite. However, the absolute volume of project financed transactions has grown steadily since 2013 (see Figure 18).

Figure 18: Market share of project-financing



Source: Green Giraffe, based on WindEurope data and internal database

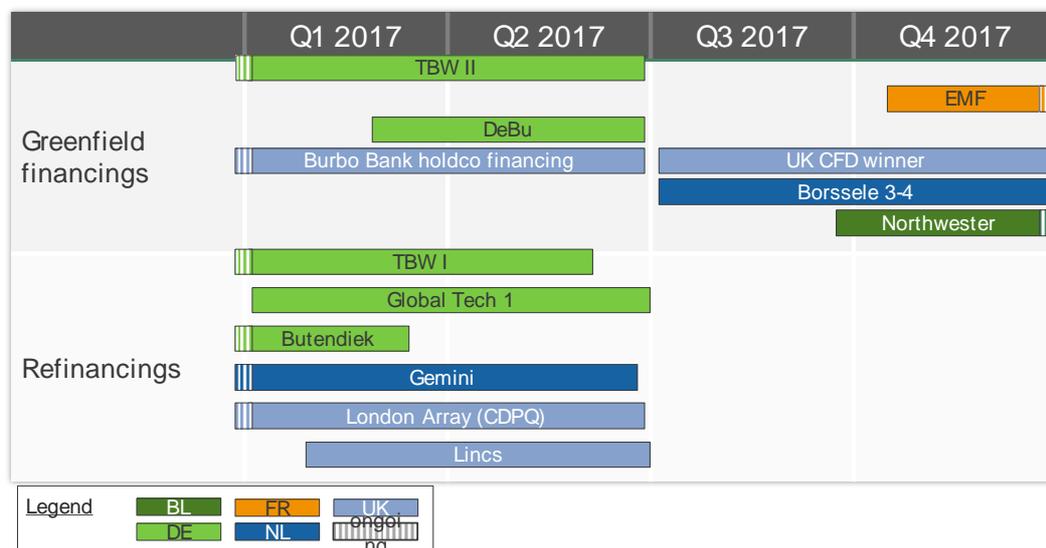
The reasons for a higher share of non-recourse funded projects compared to the industry's infancy years is driven by the following:

- The parties which used to prefer the balance sheet route, utilities, are now seeing severe constraints on their ability to fund projects in full themselves, under pressure from investors and rating agencies to reduce their corporate debt. They will now either use project finance themselves or sell part of the project to investors which want to use project finance.
- There is a growing number of experienced independent developers which are competent enough to bring a project to the stage it can be built, but do not have the funding themselves. Such developers, like Parkwind, WPD, Deepwater and Northland Power, typically raise project finance both to raise the necessary funding and to improve the return on equity of their investment.
- More importantly, the project finance market has shown itself to provide sufficient depth and capacity to fund large scale offshore wind projects on competitive terms (like the €2.8 billion, 600 MW Gemini project in the Netherlands reaching financial close in 2014, or the £2.2 billion/ equiv.€2.6bn , 588 MW Beatrice project in the UK reaching financial close in 2016).
- Cost of project financing has come down due to increased confidence from lenders.

With close to 50 lenders which have taken offshore wind risk today - of which the majority have construction exposure - at least €3-5 billion in risk commitments are available per year from the commercial market. In addition, public financial institutions like export credit agencies, the European Investment Bank, or national institutions like KfW (Germany) or the GIB (UK) have been willing to provide substantial funding to the sector as part of broader policies to support investment in low-carbon projects. They will typically contribute as much and often more than all the commercial banks put together in any given deal.

Project finance funding of offshore wind projects can be considered as a mainstream option and indeed a substantial number of projects are expecting to use that route in the coming months (see Figure 19). The availability of project finance (and construction equity) has made it possible for relatively small players to successfully bring projects to financial close and to full operation on a regular basis, and there is no reason to believe that offshore wind needs to be reserved for the larger utilities.

Figure 19: Pipeline of project financed projects



Source: Green Giraffe, based on WindEurope data for new installations and internal database for project finance transactions

In 2012, the Crown Estate market study on the UK offshore wind market projected that market growth could be constrained by utility balance sheets and a capital gap⁴⁶. However, access to capital has not proven to be a constraint as has been consistently confirmed among interviewees. The liquidity of the market has increased over the last years indicating increased levels of trust by funders in the sector and industry stakeholder capabilities. Additionally, market growth has been slower than projected, which contributed to the liquidity due to lower demand.

The leverage of equity (20-25% equity / 80-75% debt) reflects a market that is considered mature by debt providers and it is unlikely that equity contributions can be reduced any further. As a reflection of increased comfort among lenders and equity providers, stakeholder interviews confirmed that internal rates on return have also seen a reduction over the last five years.

An institutional funder interviewee expects there is little room for further reduction of the cost of debt and equity. In fact, there is a risk that established debt and equity investors may struggle to sell-down and divest to investors with little or no experience in the market that are not comfortable assuming the sector risks at a low return. Such development may create bottlenecks in freeing up capital to finance higher-risk construction.

4.3 SUPPLY CHAIN

The technologies used in offshore wind farms are still evolving and have led to a greater choice of technology options available to developers, albeit some with a limited track record. The majority of offshore wind projects that are operational in 2016 relied on a small number of WTG models available in the market, however, the limited choice also led to a relatively large track record of cumulative capacity to be built in a short timeframe. It needs to be acknowledged that there is a limited track record of offshore wind farms in late operational life.

⁴⁶ Redpoint. Baringa and GL Garrad Hassan. 2012. *UK Offshore Wind Market Study – Final Report*. available at: <https://www.thecrownestate.co.uk/media/5494/ei-km-in-pe-market-112011-uk-offshore-wind-market-study.pdf>

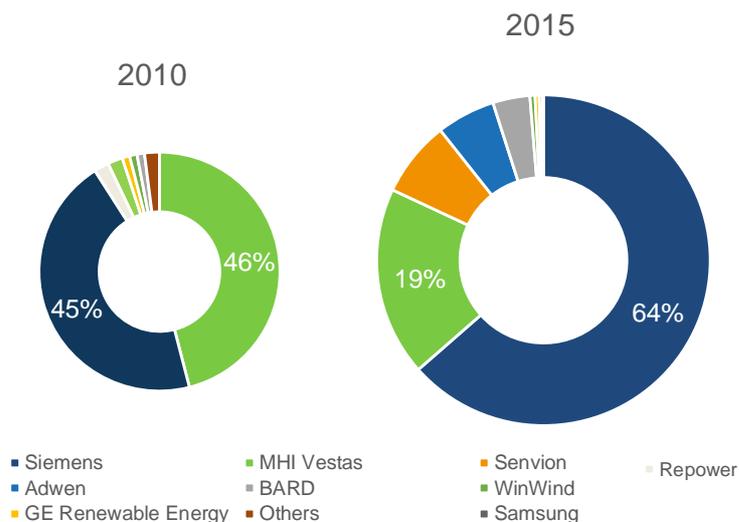
Of the 11.5 GW cumulative capacity offshore wind installed by June 2016, only 5.8% has been in operation for more than 10 years and only 24% have been in operation for more than 5 years respectively. As such, long-term performance is yet to be validated.

The average WTG size installed in 2015 was 4 MW. The industry trend of increasing WTG size is continuing with projects under development typically looking to deploy WTGs with 6 MW to 8 MW capacity. This trend also drives the continuous innovation in foundation design and array cable structures. Monopile foundations, for example, were projected to be only viable to water depths of ~30m. However, the evolution of the industry and logistics has shown that monopiles can be successfully deployed in greater depths and for bigger WTGs. The industry is working on improving design codes as operating data show that foundation designs have potentially greater redundancy than required for safe operation and to meet the design life. As such, there is considerable cost reduction potential to further optimise conventional foundation designs. In parallel, the industry is working on new design concepts, including floating foundations that are currently in a test and demonstration phase, but expected to reach commercialisation within the next decade.

4.3.1 WTG Suppliers

As shown in Figure 20, two companies, Siemens and MHI Vestas Offshore Wind (MVOW), dominate the WTG supply market and are responsible for 82% of European offshore wind capacity, as of the end of 2015.

Figure 20: Cumulative operational capacity of WTG suppliers, 2010 and 2015



Source: Mott MacDonald analysis, WindEurope (was EWEA) Statistics 2015

SIEMENS

Capacity installed (Europe): 7,002 MW

Since 1980, with the development of the first 22kW wind turbine, **Siemens** (originally Bonus Energy) has built a track record for the development of wind energy devices. Nowadays Siemens is a global leader, with more than 27 GW of wind power installed to date, of which 7.3 GW is offshore wind capacity.

Siemens has held the worldwide leading position in offshore wind turbine sales since 2008, albeit with a reduction in market share recently. The company's success has primarily been based around a 3.6/4 MW unit. However, Siemens has scaled up its offerings with 6 MW and 7 MW units and its next generation of 8 MW units. In 2010, Siemens also acquired minority shares in the offshore wind installation company A2SEA.



Capacity Installed: 2,040 MW

MHI Vestas Offshore Wind (MVOW) was founded in April 2014, as a 50/50 joint venture between Vestas Wind Systems and Mitsubishi Heavy Industries. Since then, MVOW has employed about 1,300 people and has orders amounting to 1.7 GW in the pipeline. A new blade factory was set up in 2015 on the Isle of Wight to manufacture the blades for the V164-8.0 wind turbine.

Vestas Wind Systems is a Danish based company and a leading manufacturer of onshore and offshore wind turbines. The company has a track record in the production and installation of more than 58,000 turbines worldwide as of 30 September 2016 and has been involved with offshore wind since 1995. Mitsubishi has been involved in the research and development of WTGs since 1980 and subsequently went on to manufacture WTGs in the range of 250 kW to 2.4 MW. While Vestas had suffered some technical and financial issues which affected its attractiveness in the late 2000s and early 2010s, since forming the MVOW joint venture the firm has regained its foothold in the industry and has become well regarded in projects currently under development. MVOW offers a range of offshore wind turbines from 3 MW units to the largest wind turbine currently available, the V164-9 MW.

Trends

The market has seen several new players entering the market but also a consolidation in ownership of market players which is typical for new markets and technologies. Market exits include Bard, Clipper, Alstom, Areva and Samsung. Ownership of WTG suppliers has transitioned from OEMs whose sole background was onshore WTG manufacturing to multi-sector-multinational technology corporations such as GE and MHI with greater financial capabilities.

A significant share of the industry's cost reduction is expected to come from the use of larger and more efficient WTG technology⁴⁷. Table 17 outlines the ten largest offshore WTGs that are under development and/or in serial production. Only two of the ten are owned by the two major players of the market to date. Another two were developed by Adwen, a joint venture between Areva and Gamesa. In September 2016, Areva announced sale of its 50% shareholding in Adwen to Gamesa to take on sole ownership of Adwen. Gamesa, in turn, is undergoing acquisition by Siemens.

⁴⁷ ORE Catapult. 2015. *Cost reduction monitoring framework – summary report to the Offshore Wind Programme Board*. available at: <https://ore.catapult.org.uk/wp-content/uploads/2016/05/CRMF-ORE-Catapult-report-to-the-OWPB.pdf>

As such, it remains yet to be seen how Siemens is going to manage its overall product portfolio after acquisition. After its involvement in Arklow Bank in 2004, GE exited the market and only returned in November 2015 with the acquisition of Alstom, taking ownership of the 6 MW Haliade technology.

Eight of the ten largest WTG models are provided by WTG suppliers with European headquarters. Assembly facilities of key components such as blades and the nacelle are typically located within Europe, however, sub-suppliers of key components may deliver from outside Europe. Chinese suppliers such as Dongfang and Ming Yang are aiming to deliver internationally, however, no Chinese suppliers had concluded a contract in Europe at the date of this report.

Table 17: Largest offshore wind turbines

WTG	Capacity	Supplier	Market readiness	Technology
V164 9MW	9MW	MHI-Vestas	Launched January 2017	Based on the V164 8MW Medium-speed geared
AD-180	8MW	Adwen	Selected for 3 French projects	Medium-speed geared
V164 8MW	8MW	MHI Vestas	Serial production	Medium-speed geared
SWT-9.0-154	8MW	Siemens	7MW version obtained type certificate in 01/2016	Direct drive
6.2M152	6.15 MW	Senvion	Serial production, prototype installed in 12/2014, 200+ units operational or under construction	High speed geared
Haliade	6 MW	GE	Commissioned on first commercial project Block Island Selected on 3 French projects and Merkur, Germany	Direct drive
SCO 6.0 MW	6 MW	Ming Yang	Prototype installed in 2014, 8 MW version is being worked on for markets in and outside China	Medium-speed geared
SL6000	6 MW	Sinovel	Launched in 2011, but only deployed in 1 commercial project to date, financial difficulties delayed development of 10 MW unit	High speed geared
Dongfang/Hyundai Heavy Industries 5.5 MW	5.5 MW	Dongfang/Hyundai Heavy Industries	Under development	High-speed geared
AD5-135	5 MW	Adwen	Serial production, more than 200 in operation of this and predecessor models	Low-speed geared

Source: Wind Power Monthly (2016), and Offshore Wind Industry (2017)

4.3.2 Foundation suppliers

Foundations are often manufactured by large steel companies, such as Bladt Industries, which has been the lead foundation supplier in the offshore wind market over the last four years (see Figure 21). Founded in 1965, Bladt is active in the offshore wind market, as well as the oil and gas industry and infrastructure (including bridges, harbour and marine, buildings and steel tanks). Bladt provides monopiles, transition pieces, XL foundations and jacket foundations for offshore wind. Since the first foundation in 2002, Bladt has delivered more than 1,300 foundations to offshore wind farms.

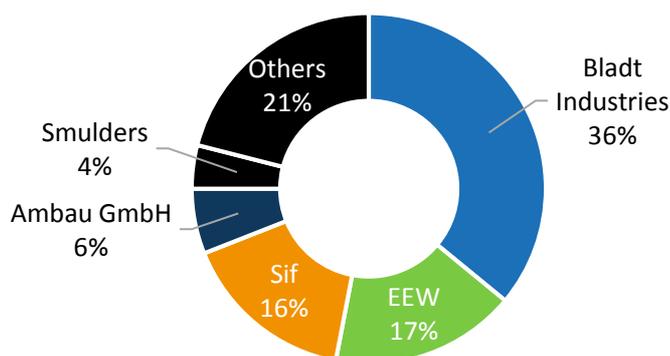
EEW Special Pipe Constructions GmbH (EEW SPC), established in 2008, is part of the larger EEW Group. Erndtebrücker Eisenwerk GmbH & Co. KG (EEW) was founded in 1936 in Germany and has developed to one of the key large-diameter steel pipe manufactures for oil & gas industry, offshore wind industry, power plants and civil construction. Manufacturing of offshore foundation is done in EEW SPCs production facilities in Rostock, Germany. In March 2016, EEW SPC manufactured the heaviest monopile at the time for the German Veja Mate offshore wind farm. The monopile has a diameter of 7.8m, a length of 82.2 and weighs 1,300 tons⁴⁸.

In 2014, Bladt and EEW SPC established a joint venture Offshore Structures (Britain) Limited, a manufacturing facility in Stockton, UK to extend its presence in the UK market⁴⁹. Sif, the third key player in the foundation market, is a Dutch steel tubular manufacturer for the offshore oil & gas and wind industry with an experience of over 65 years and more than 1,200 foundations manufactured to date⁵⁰.

While most of the foundation manufacturing is based in Europe, there are some examples of component manufacturing based elsewhere. CS Wind supplies transition pieces for WTG and Offshore High Voltage Substations (OHVS). The company can produce 2,300 towers annually at its production facilities in Vietnam, China and Canada.

Foundation design is the one of the key aspects and risk factors in the development of an offshore wind farm with only a few capable foundation designers (such as the Danish consultancies Ramboll and COWI) being available in the market.

Figure 21: Market share of foundation suppliers (period 2012 – 2015)



Source: Mott MacDonald analysis, Wind Europe (formerly EWEA) Statistics 2015

⁴⁸ EEW Special Pip Constructions corporate website, available at: <http://www.eewspc.com/products.html>

⁴⁹ 4C Offshore. 2015. *Offshore Structures (Britain) opens its doors*. available at: [http://www.4coffshore.com/windfarms/offshore-structures-\(britain\)-opens-its-doors-nid2374.html](http://www.4coffshore.com/windfarms/offshore-structures-(britain)-opens-its-doors-nid2374.html)

⁵⁰ Sif group corporate website, available at: <https://sif-group.com/en/references/13-references>

4.3.3 Cable suppliers

Cabling for offshore wind projects is split between array cables (between turbines) and export cables (which takes electricity generated by the farm to the substation).

Nexans has been a key provider for array cables over the last three years, with over 405 cables (25% market share) manufactured and energised (see Figure 22)⁵¹. The French cable supplier was founded in 2000 and its core businesses includes power transmission and distribution, energy resources (renewables, Oil & Gas), transportation and building. Nexans supplies and lays MV subsea array cables as well as MV and HV export links to the onshore substation and owns a cable-laying vessel, the C/S Nexans Skagerrak.

Prysmian Group is a key player in both the export cable (45% market share – see Figure 23) and array cables (23% market share). Prysmian Group is a global player in energy and telecom cable and systems sectors, with over 140 years of experience. Headquartered in Milan, Italy, the group was established through a merger of Prysmian Srl and Draka in February 2011. Prysmian Group owns three cable-laying vessels; Ulisse, Giulio Verne and Cable Enterprise.

The German cable manufacturer, NSW (Norddeutsche Seekabelwerke) had a 26.3% share in the array cable market in 2015, up from 16% between 2013 and 2015. Founded in 1899, NSW core business lies within the submarine cable technology and communications. NSE covers the design, manufacture, delivery and installation of the cables utilising the NWS operated cable lay barge Nostag 10.

JDR Cable Systems, with 13% of the array cable market share between 2013 and 2015, was established in the early 1990s with the merger of the British Jacques Cable Systems and the Dutch De Regt Special Cable company. Its main manufacturing facility to supply the offshore wind market is in Hartlepool, UK, and JDR supplied the inter array cabling the Greater Gabbard project in the UK and the Meewind project in Germany.

NKT cables was founded in 1891 and has presence in China, Germany, Sweden, Poland, Czech, Norway and Denmark. NKT provided the infield and export cables for the first commercial offshore wind farm in Germany, Baltic 1. In September 2016, it was announced that NKT cables will acquire ABB’s HV cable business, including a new cable laying vessel to be delivered in Q1 2017^{52,53}. ABB HV Cables is a key market player in the high-voltage cable system market for submarine power transmission systems.

Figure 22: Array cable supplier (period 2013 – 2015)

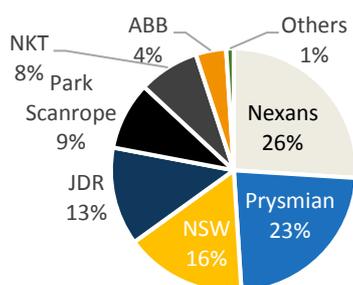
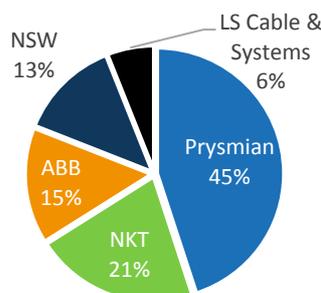


Figure 23: Export cable supplier (2015)



Source: WindEurope

⁵¹ Nexans corporate website, available at: http://www.nexans.com/eservice/Corporate-en/navigate_-10/Global_expert_in_cables_and_cabliging_systems.html

⁵² Bloomberg. 2016. *ABB to sell cables business to Danish NKT for US\$ 934 million (equiv. €884)*. available at: <https://www.bloomberg.com/news/articles/2016-09-21/abb-to-sell-cable-business-to-nkt-cables-for-934-million>

⁵³ NKT cables corporate website, available at: <http://www2.nktcables.com/about-us/news-events/news/news-report/news/nkt-cables-to-acquire-abbs-high-voltage-cables-business-creating-a-leading-power-cable-company.html>

4.3.4 Installation contractors

Installation can be broken down to three main categories: foundations, WTGs and cables. As mentioned above, most cable suppliers own cable laying vessels. Other companies specialised in cable laying operations are Siem Offshore Contractors (SOC) and VBMS BV. Installation of offshore cables requires a dedicated cable laying vessel (CLV) or barge equipped with a turntable storage facility. The handling of the cable during installation is important as specific cable properties, such as the limit of the bend radius or the cable burial depth, define the installation methods.

Key installation companies are A2SEA (partially owned by Dong), GeoSea (DEME Group), Scaldis Salvage (DEME Group), Jan de Nul Group, MPI Offshore, Seaway Heavy Lifting, Fred.Olsen, and Van Oord. Most of these installation companies come from a marine oil & gas background and existing vessels have been adapted to execute turbine and foundation installation.

Offshore substations are usually developed by consortia or joint ventures, made up of a civil and an electrical company and delivered under an EPCI approach. Offshore substation design services and equipment, such as transformers and switchgear, are usually provided by large players in electrical system supply, such as ABB, Siemens and Alstom (now GE Grid). Manufacturers of the topsides include companies such as Bladt, Engie Fabricom (formerly Cofely Fabricom GDF Suez), and Herema Hartlepool Ltd.

4.3.5 Geographical location of industry sectors

Wind turbine manufacturing

With the sector's infancy in Denmark, a number of WTG manufacturing facilities in the offshore wind industry are located in these areas including Brande, Aarborg and the port of Esbjerg in Denmark. Since then, the industry has seen a growth and geographical diversification of the supply chain facilities, including the hubs in Rostock, Bremerhaven and Cuxhaven in Germany, as well as the Humber region in the UK where Siemens is establishing blade manufacturing facilities and Dong a service harbour.

Emerging markets in which no projects are yet operational aim to establish at least a partial domestic supply chain, including France, the USA and Chinese Taipei. In France, the use of a domestic supply chain by developers was encouraged through local content requirements in the auction design. In response, Alstom has established nacelle assembly facilities in Saint-Nazaire.

The USA has a strong focus on ensuring local participation in the sector as it grows. The country has an indigenous supply chain with substantial oil and gas experience and the supply chain has reasonable transferrable capabilities in cable and foundation manufacture and marine contracting. However, availability of large vessels for foundation and WTG installation is currently a challenge, in part due to legislation which heavily restricts the operation of non-US flagged vessels in US waters ("The Jones Act"). Alstom, which is in the process of being procured by US firm General Electric, provided the WTGs for Block Island and has a strong presence in the USA. Siemens is also committed to the country and is working to supply a number of projects in development.

Chinese Taipei is looking to grow its local supply chain for offshore wind but appears set to use Siemens and other European turbines in the short term.

For larger components and assembly, manufacturing facilities typically require harbour access to mitigate requirement for road transport, which may not be feasible for greater dimension parts. While wind turbine manufacturers generally assemble key components, they do not necessarily manufacture all key components in-house, including procurement from non-European facilities.

Balance of plant

Balance of plant manufacturing facilities are more widely spread, including the UK, Germany, Netherlands, Belgium, France, Spain, and Korea. The majority of the supply chain and value creation to date though remains in Europe.

However, a number of plans for manufacturing facilities across Europe have been cancelled or put on hold over the last years due to delays in projects and market growth, as well as a lack of confidence in the size of the market beyond 2020⁵⁴. Following the Brexit vote, investors in the UK supply chain are facing increased uncertainty levels. Siemens, for example, announced putting further investments in the UK supply chain on hold due to the uncertainties caused by the Brexit vote⁵⁵.

Overall, as was confirmed by stakeholder interviews, the level of competition has improved and the overall supply chain is perceived to be more robust than a few years ago.

⁵⁴ ORE Catapult. 2015. *Cost reduction monitoring framework – summary report to the Offshore Wind Programme Board*. available at: <https://ore.catapult.org.uk/wp-content/uploads/2016/05/CRM-F-ORE-Catapult-report-to-the-OWPB.pdf>

⁵⁵ The Guardian. 2016. *Siemens freezes new UK wind power investment following Brexit vote*. available at: <https://www.theguardian.com/environment/2016/jun/28/siemens-freezes-new-uk-wind-power-investment-following-brexit-vote>

4.4 COMPARATIVE ANALYSIS OF NATIONAL INDUSTRIES

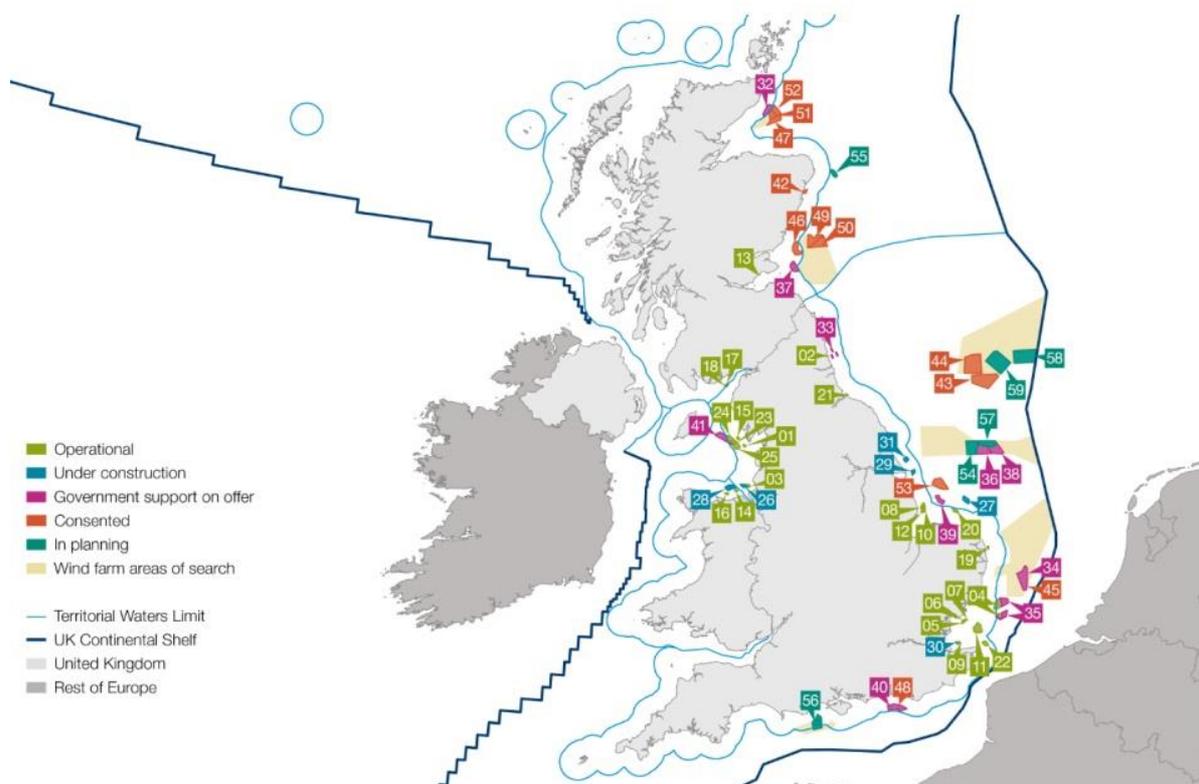
4.4.1 Overview

This section sets out a comparative analysis of industry structures in the key European offshore wind markets the UK, Germany and the Netherlands, as well as emerging markets.

4.4.2 United Kingdom

The United Kingdom has been one of the driving forces behind development of the offshore wind sector in the 2000s, and represents the largest offshore wind market in the world, with just over 5 GW of operational capacity as of June 2016. Figure 24 shows a map of the UK’s offshore wind developments.

Figure 24: UK offshore wind map



Source: Crown Estate, 2016

The UK industry is characterised by a high level of international participation. Major developers that currently own operating offshore farms are Dong, Innogy, E.ON, Vattenfall, SSE, Trianel and Iberdrola. Note that only one of these developers (SSE) is indigenous, after the market exit of Centrica and the acquisition of Scottish Power by Iberdrola.

Large utility-developers, as opposed to IPP-developers, dominate project development with almost 70% ownership of operating windfarms. Dominance of the utility-developers goes hand in hand with the historically relatively low use of project finance, with the utility developers preferring to fund projects on balance sheet. However, there are signs of change, given the requirements of increased investment volumes due to larger wind farms.

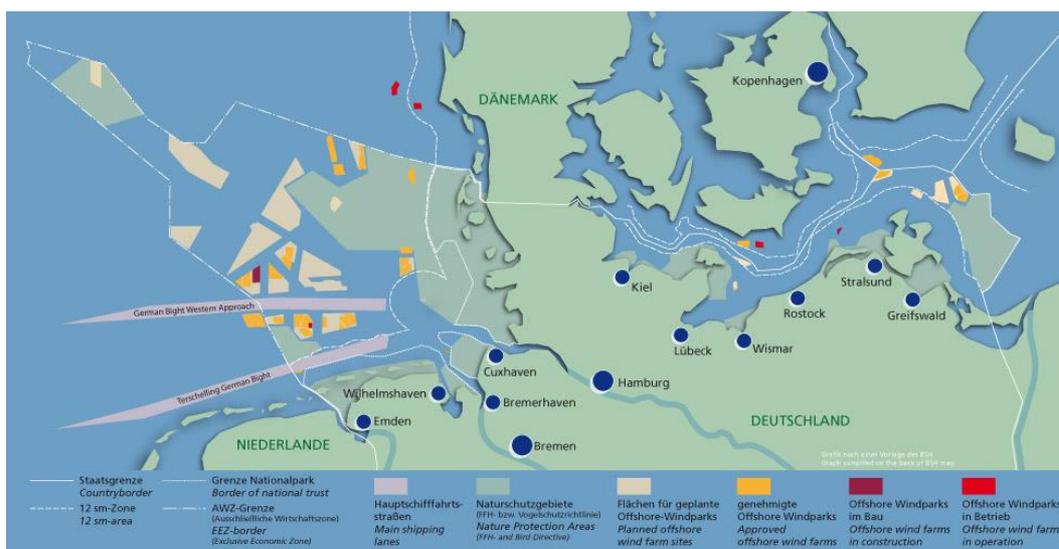
As the UK industry has matured the risks (perceived and real), particularly in the operational phase of an offshore wind farm, have reduced. Lower risk perception has brought in more risk averse investors into commissioned projects, allowing large utilities to recycle equity into project development.

The UK does not have an indigenous WTG supplier, however it has managed to attract both Siemens and MHI Vestas to invest in manufacturing facilities. It has also attracted other parts of the supply chain to invest, such as Offshore Structures Britain (OSB), which is a joint venture between a German steel fabricator and Danish steel construction company. OSB now produces large tabular offshore wind foundations on the River Tees.

4.4.3 Germany

Germany has the second largest 2020 and 2030 deployment estimate in Europe, with the national target being 6.5 GW by 2020 and 15 GW by 2030. Despite setting ambitious targets, Germany did not install its first offshore wind farm until 2010. A map of German offshore wind developments is shown in Figure 25.

Figure 25 German offshore wind map



Source: <http://www.southbaltic-offshore.eu/regions-germany> South Baltic OFF.E.R – Offshore Wind Energy Regions

Major players in the German offshore wind industry tend to either be based or at least have offices in Hamburg, which acts as an unofficial hub for offshore wind in the country. Numerous suppliers are based around the harbours of Bremerhaven and Cuxhaven, which are well situated to serve North Sea projects.

Germany is home to several successful offshore wind developers, including utilities such as Eon, Innogy and Stadtwerke Munchen, and independent developers such as WPD. However, like the UK, Germany has attracted several international developers, such as Dong, Vattenfall and SSE. Germany has a higher involvement of IPP-developers (just over 50%) than in the UK.

The German offshore wind farm industry has benefitted from early adoption and strong investment in its onshore wind industry. Siemens, the largest WTG supplier, is based in Germany along with the smaller WTG manufacturer Senvion. The country is also home to suppliers of various other offshore wind turbine services and equipment and several large harbours.

4.4.4 The Netherlands

The Netherlands has been relatively slow in adopting offshore wind, with only 518 MW operational as of June 2016. However, the country has significant goals, with tenders for procurement of 3.5 GW of capacity announced over the period 2015 to 2019 to meet their 2023 energy targets, representing a substantial opportunity for the industry. The success of the first two tenders has triggered a motion to add a further wind farm to the current 2023 build programme, as well as call for further expansion up to 2030.

Unlike the UK and Denmark, where a large percentage of projects has been developed by utilities, the Netherlands has attracted more independent developers. Princess Amalia was the first project financed offshore wind farm when it achieved financial close in 2007, and in 2014, the Dutch offshore wind project Gemini achieved financial close. This 600 MW scheme represents the largest renewables facility ever financed through a project finance scheme and forms a substantial industry milestone. The recent auction for Borssele I&II was awarded to utility developer Dong and, as such, following an industry wide trend of favouring utility developers under auction regimes. Borselle III & IV was awarded to a consortium of Shell, Eneco and Mitsubishi/DGE.

The Netherlands is also home to several the largest marine contractors in offshore wind, including Van Oord and Seaway Heavy Lifting. Finally, the country has several harbours which have been used in offshore wind, not only in The Netherlands but also to service projects in Belgium and the UK.

4.4.5 Industry structure in emerging markets

By the end of 2016, total offshore wind installed capacity was 14.4 GW, of which 87% was installed in Europe and 11% in China. Demonstrator plants are installed in Japan, South Korea and during 2016 the first offshore wind farm was constructed in the US. In terms of policy commitments and outlook, key emerging markets outside Europe include China, the US, Japan and Chinese Taipei. India is soon to join this group of emerging offshore wind markets, with announcements of a centralised site selection policy⁵⁶.

USA

The USA commissioned its first offshore wind farm in 2016; the 30 MW, 5 turbine Block Island offshore wind farm developed by Deep Water Wind. The USA has a well-developed onshore WTG manufacturing sector (including suppliers such as GE) and an established offshore oil & gas industry. However, the USA lacks appropriate vessels for providing O&M services and WTG lifting, which means European vessels are currently required.

China

China relies almost entirely on a domestic supply chain and market entry for international suppliers has also proven to be challenging in the onshore wind market. China's industry structure differs from other offshore wind markets, in that the industry is not using EPCI contract packages, but procures design separately from supply and installation. Planning and project development is jointly undertaken by developers and so called 'design institutes'. With only over 1 GW installed at the end of 2015, the offshore wind manufacturers evolved from onshore WTG manufacturers, as was seen in Europe. Other aspects of the supply chain, including balance of plant scope of work, are still immature. Experience from the offshore oil and gas sector has been utilised for installation of foundations and electrical infrastructure.

Japan

No commercial scale project has yet been built in Japan. In the onshore wind sector there is a preference for domestic suppliers (around one third of WTG are from domestic suppliers), which is likely to be repeated offshore, particularly with several domestic OEMs developing bespoke turbine designs to withstand typhoon conditions. With Vestas's merger with MHI for offshore wind, MHI Vestas would appear well positioned, in addition to Hitachi and Japan Steel Works, who have provided turbines for early demonstration projects.

⁵⁶ Clean Tech Media. 2015. *India approves offshore wind energy policy*. available at: <https://cleantechnica.com/2015/09/11/india-approves-offshore-wind-energy-policy/>

4.5 LESSONS LEARNED

The industry has developed in recent years and may be entering a market maturation phase in key established markets such as the UK and Germany

Project developers and supply chain have grown in experience, and there are greater levels of trust from investors and lenders. This greater confidence in the industry, having established effective risk mitigation strategies, has led to lower costs of funding, and attracted new risk averse funders. Additionally, the market has consolidated in key markets over the last years leading to fewer, more mature players in today's market.

On the technology side, increasing options, in size, design and manufacturer, are becoming available to developers albeit with limited track record to date. The industry has transitioned from WTG suppliers having solely an onshore wind background to joined ownership with global multi-technology firms.

The market has been comprised of two distinct models: the utility and IPP models

Utility-developers could typically rely on balance sheet, had greater risk appetite, whilst IPP-developers relied on non-recourse finance and therefore operated under the lenders' approach to risk which is more conservative. Utility-developers tended to use a greater number of construction contracts, resulting in greater interface risk whereas IPP-developers had limited number of contracts and lesser interfaces. Utility-developers typically took over O&M contractor role after end of warranty period whilst IPP-developers commissioned OEMs for 10 to 15 years to undertake WTG O&M.

Developer models have evolved, with growing use of project finance by utility developers, and a trend towards development consortia

- Evolution of developer models:
 - Utility-developers are now also using non-recourse finance because the cost of debt financing has reduced and project size has increased therefore making it difficult to source funding from equity alone.
 - The contracting strategies of utilities and independent power producers have become more similar, with utilities using less contracts than they used to.
 - Larger project sizes, hence higher investment volumes, has caused a recent trend towards building consortia in order to spread the risk across parties.
 - These trends are driven by greater confidence in the market by investors and lenders and improvement of capabilities across the supply chain.
- Key success factors of developers are:
 - Sound financial capabilities.
 - Technical capabilities and experience of developer team.
 - Robust planning with fall-back plans.
 - Robust project agreements.
 - Appointment of experienced contractors.

Predictions of capital constraints have not been borne out, due to availability of project finance and reduced ambitions

The predictions of capital constraints for offshore wind were based on balance sheet analysis of the key utilities. However, there is now a wide availability of project finance for offshore wind, due to the industry's maturity and trust in the sector. The availability of project finance (and construction equity) has made it possible for relatively small players to successfully bring projects to financial close and to full operation on a regular basis, and there is no reason to believe that offshore wind needs to be reserved for the larger utilities.

Emerging, non-European, markets have significant supply chain capabilities due to pre-existing onshore wind and oil & gas industries. However, the lack of vessels for WTG lifting and O&M servicing could present bottlenecks.

The established markets in Europe (the UK, Denmark, Germany, Belgium, and the Netherlands) have benefitted from mature onshore wind and oil & gas industries with well-developed supply chains. While in the largest market, the UK, there is limited indigenous WTG manufacturing capability, the country has benefitted from proximity to other European countries. Northern Europe has become a hub for offshore industry, where individual countries' industries can complement each other.

The lack of vessels with the necessary capabilities could prove a bottleneck for emerging markets. Individual countries may benefit from becoming part of regionalised industries until a critical mass of offshore wind deployment is achieved. Vessels may also require the ability to be utilised in the offshore oil & gas sector.

Industry players need to better communicate the success story and benefits of offshore wind

Public perception of the offshore wind industry is positive due to the environmental benefits. However, lack of public support for offshore wind is a potential barrier to future development due to the perceived lack of reliability and high cost⁵⁷. While there are some eye-catching examples of offshore wind public relations campaigns, such as the 75m rotor blade installed in the city of Hull, the UK⁵⁸, more can be done to improve the industry's public standing.

⁵⁷ Hattam et al. 2015. Public Perceptions of Offshore Wind Farms. Croan Estate. available at: <https://www.thecrownestate.co.uk/media/501973/ei-public-perceptions-of-offshore-wind-farms.pdf>

⁵⁸ See: <http://www.bbc.co.uk/news/uk-england-humber-38547052>

5 PROJECT RISK MANAGEMENT

- **Collaboration within the industry helps to manage developer risks on large-scale projects under auction regimes**
- **More successful projects build a strong management team and have fall-back plans in place**
- **Strong relationships with regulators, executing authorities and third parties lead to more successful projects**
- **Continued innovation is required to achieve cost reductions**
- **Developers do not require all risks to be mitigated but regulatory frameworks need to ensure risk-reward balance for developers**
- **Allocation of grid connection risk to the grid operator by regulators requires effective performance incentives for the grid operator**

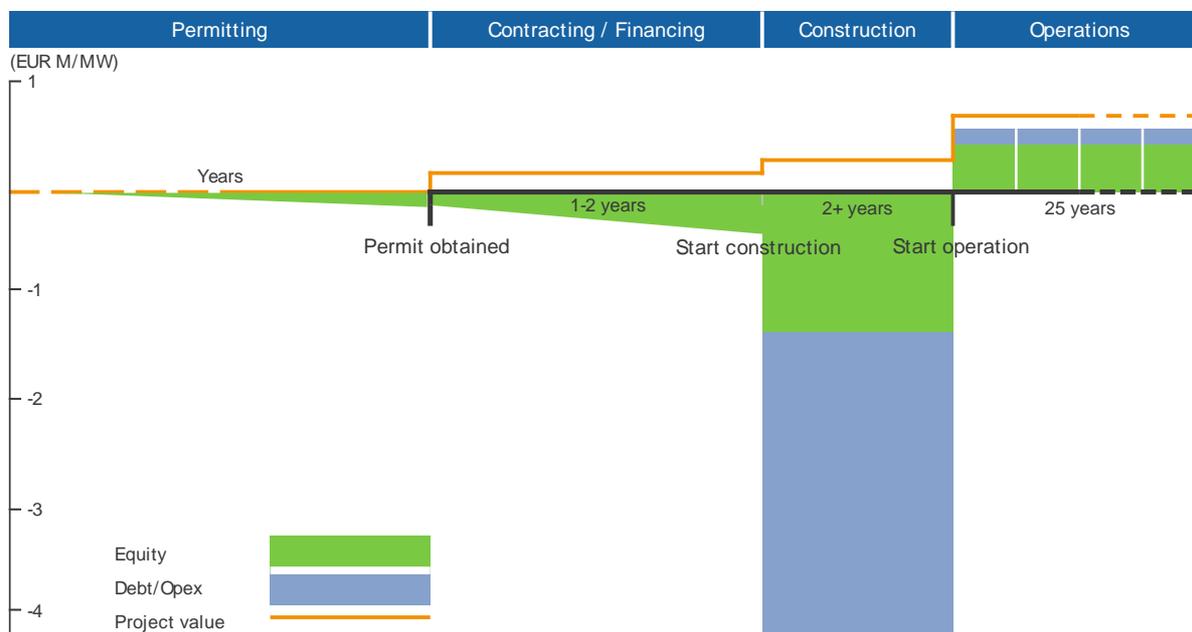
As outlined in Section 3, regulatory frameworks act as enabling factor for offshore wind developments by providing clear rules and requirements for developers on how to secure sites, a grid connection, and a permit to construct and operate. To attract developers and investments, regulatory frameworks also have to provide risk mitigation where developers and/or the market cannot (yet) assume or afford to assume such risks. As such, the risk profile for developers depends not only on the regulatory framework design but also on site specific technical and environmental risks, and the status of the wider wind offshore market and industry environment, as well as competing markets and technologies. This section focuses on the developers' perspective on risks and risk mitigation strategies and outlines:

- Project lifecycle risks
- Developers' risk mitigation tools
- Developers' risk mitigation strategies
- Trends in developers' risk profile and drivers

5.1 PROJECT LIFECYCLE RISKS

This section sets out key project lifecycle risks, irrespective of the allocation between developers and regulators. Figure 26 highlights the basic stages of project development and expenditure profiles.

Figure 26: Expenditure over the project lifecycle



Source: Green Giraffe

Key project phases are:

- **Allocation risks** – Risk of obtaining the right to develop, construct, operate and receive revenue incentive
- **Price risk** – Risk of not obtaining an adequate price for the project (i.e. in a competitive auction) or price uncertainty if exposed to changes in the wholesale electricity market.
- **Development risk** – High risk, mainly due to cost of geotechnical and geophysical studies, only attracts funders with high risk appetite, project is subject to risk of cancellation
- **Funding risk** - Relatively risky as a project prior to Financial Close or Final Investment Decision remain virtual and can be subject to cancellation
- **Construction risks** - The full amounts required to build a project are committed, the project becomes “real” and can attract different investors, projects become valued on the basis of their future cash flows, discounted at a rate which is the rate of return expected by the investors. Given the amounts required, and the different (lower) risk profile, new investors typically get involved at this point in time.
- **Operation risks** - At completion (“commercial operation date” or “COD”) a project is fully operational and starts generating cash flow. This phase typically lasts for 20 to 25 years. With constructions done, the project is further de-risked and can attract yet-more-risk-adverse investors, with a lower cost of capital.

Table 18 outlines generic project lifecycle risks of an offshore wind project during its lifecycle which are further detailed in Section 5.3. Our categorisation of risks are based on Mott MacDonald experience, interviews and the literature^{59,60,61}.

Table 18. Project lifecycle risks

Risk category	Risks	Potential impacts
Allocation risk	Risk of securing rights to develop, construct and/or operate an offshore wind site and to obtain revenue support	Introduces uncertainty and challenges in retaining and growing capabilities
Development risks	Wind resource and/or energy yield lower than expected Environmental risks Secure permitting Ground risk Grid connection Securing tariff Adverse change of regulatory framework	Loss of development expenditures (potentially EUR 10s of millions) in case of project cancellation
Funding risks	Risk of not finding enough funders Risks of delay in funders approval Cost of funding greater than expected	Delays Lower developer margin Reduction / loss of tariff due to delays
Construction risk	Weather risk Interface risks Availability of contractors and equipment New technologies Health and safety risks Quality risks	Cost overrun Delay of construction contractors Delay of grid connection works Project cancellation / suspension
Operation risk	Weather and accessibility risk Major intervention risk Lead time risk for major spares and logistics equipment Availability of specialist O&M personnel Health and safety risks Quality risks	Performance / energy yield below expectations Operating cost greater than budgeted

⁵⁹ Altran and Arthur D Little. 2011. *IEA-RETD: Risk Quantification and Risk Management in Renewable Energy Projects*. IEA-RETD. available at: <http://iea-retd.org/wp-content/uploads/2011/11/RISK-IEA-RETD-2011-6.pdf>

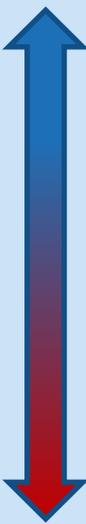
⁶⁰ Mott MacDonald. 2011. *Accelerating the deployment of offshore renewable energy technologies*. IEA-RETD. available at: <http://iea-retd.org/wp-content/uploads/2011/09/ADORET-Final-Report-2011-2-Main.pdf>

⁶¹ IRENA. 2016. *Innovation Outlook – Offshore Wind*. available at: http://www.irena.org/DocumentDownloads/Publications/IRENA_Innovation_Outlook_Offshore_Wind_2016.pdf

5.2 DEVELOPER RISK MITIGATION TOOLS

Table 3 outlines the principal risk mitigation tools available to developers in order of preference and cost impact. Where possible the aim is to wholly eliminate or avoid risk at a development and design stage. Where residual risks cannot be fully foreseen or mitigated through design out, passing on to third parties is not viable, contingency budgets and insurance may be required. With the sections below, key developer risks are highlighted as well as established or preferred risk mitigation tools. Developer’s risk mitigation strategies for particular risk categories are outlined under Section 5.3.

Table 19. Risk mitigation tools

Risk mitigation tool	Objective	Example	Cost impact on developers
Design out	Eliminate risks by development of safe designs or avoidance of risk through technology selection.	E.g. Revision of design standards for foundations to mitigate grouted connection failure in monopiles.	 <p>Low</p> <p>High</p>
Pass on to third parties	Pass risks on to parties that in control of and have the capabilities of managing the risk	E.g. Pass on P50 weather risk to construction contractors	
Contingency	Allow for a contingency budget for risks that cannot be mitigated with above strategies	E.g. Include construction contingency for known and unknown unknown such as residual interface risk E.g. Include float for delays in schedule of works between the works of different construction contracts	
Insurance	Take out insurance for risks that cannot be mitigated with above strategies	E.g. Insurance for public liability or unforeseen loss,	

5.3 DEVELOPER RISK MITIGATION STRATEGIES

This section sets out developers’ risk mitigation strategies for each of the key project risk categories based on industry experience to date as well as feedback from stakeholder interviews. Throughout the section, we present a series of risk tables which categorise risks through the project lifecycle by their risk level. We also present risk mitigation options for both developers and regulators. These tables can be used as a reference for industry stakeholders. The risks are colour coded as follows:

- Red (high): material impact on the Developer’s project business case, potential risk of project cancellation or loss.
- Amber (medium): moderate to high impact on the Developer’s project business case, however low risk of project cancellation or loss.
- Green (low): low to moderate impact on the Developer’s business case.

5.3.1 Allocation and development risks

The developer’s risk profile can vary greatly depending on the regulatory framework design. As such, we have reviewed the impact on developers’ risks and risk mitigation strategies of two contrasting regulatory framework as set out under Table 20, as well as the required or desired regulatory risk mitigation. Scenario A largely reflects the traditional model that was applied in European offshore wind markets prior to the introduction of auctions and Scenario B reflects a central model auction, whereas site selection and development are undertaken by the regulator.

Table 20. A comparison of the developers’ risk profile

Scenario	Site selection	Site investigation	Consenting/ permitting	Grid design & construction	Revenue incentive	Developer risk	Developer control
A – Traditional model	Developer	Developer	Developer	Developer	Tariff for eligible technologies	High	Low
B – Central Auction model	Regulator	Regulator	Regulator	Grid operator	Tariff via auction	Low	High

Prior to the introduction of competitive auctions to secure development rights and/or revenue support in Europe, regulators typically determined requirements to obtain a construction permit and grid connection and provided such requirements were fulfilled, eligible technologies would receive defined revenue incentives. This approach provided developers with relative certainty over the level of revenue support and timescale requirements to secure the revenue support, however left the development risk entirely with the developer.

Under competitive auction regimes, developers no longer have security if and in which auction they may be successful, hence leaving a great level of uncertainty over the size, geography and nature of their project pipeline that will proceed to construction.

Table 21 outlines the developers’ risk profile under regulatory framework scenario A (traditional model) and risk mitigation that can be applied by developers and regulators.

Table 21. Risk mitigation strategies for development risks under Scenario A

Developer risk	Developers' mitigants	Risk level post developer mitigation	Regulator's mitigants	Risk level post regulator mitigation
Risk of project cancellation during development phase and loss of substantial development cost (potentially EUR 10s of millions) due to <ol style="list-style-type: none"> 1. Technical or environmental fatal flaws 2. Adverse regulatory changes during long timescales from project initiation to COD 3. Adverse market changes / cost increase 	<ul style="list-style-type: none"> • Creating consortia to share development risks • Apply good industry practice to site selection, site investigations • Maintain a diverse pipeline to compensate losses with successful projects 	High	<ul style="list-style-type: none"> • Zoning/pre-selection of eligible areas for offshore wind development by regulator to rule out key risks for the feasibility of a project • Tariff level support that accounts for development cost and risk • Clear permitting regime and grid connection regime 	Medium
Risk of (planned) tariff depreciation (based on COD date) or phase-out of tariff	<ul style="list-style-type: none"> • Apply good industry practice to site development and construction to mitigate delays and tariff depreciation • Float in schedule • Reduction in project capacity to complete the project in time to secure tariff 	Medium	<ul style="list-style-type: none"> • Provide long-term visibility over regulatory frameworks • Avoid frequent and/or retroactive changes to regulatory frameworks • Allow for transition period when frameworks are changed 	Low

Table 22 outlines the developers' risk under regulatory framework scenario B (central auction model) and risk mitigation that can be applied by developers and regulators.

Table 22. Risk mitigation strategies for development risks under Scenario B

Developer risk / impact	Developers' mitigants	Risk level post developer mitigation	Regulator's mitigants	Risk level post regulator mitigation
Lack of financial capabilities to participate in auctions	<ul style="list-style-type: none"> • Seek partners 	Low	n/a	n/a

Developer risk / impact	Developers' mitigants	Risk level post developer mitigation	Regulator's mitigants	Risk level post regulator mitigation
Bid loss (cost of bidding)	<ul style="list-style-type: none"> • Create consortia with required technical and financial capabilities to increase chances of winning, spread risks and enable participation in greater number of auctions • Market consolidation 	High	<ul style="list-style-type: none"> • Provide clear information on project risks and findings of site investigations to minimise uncertainties for bidders • Define realistic tender requirements • Provide clear tender evaluation criteria to encourage participation of bidders reasonable chance of succeeding 	High
Obsolete development capabilities	<ul style="list-style-type: none"> • Transfer to deploy in markets where project development is developer responsibility • Separate development and construction business, offer developer capabilities to regulators 	Known impact	<ul style="list-style-type: none"> • n/a 	n/a
Lack of control/ uncertainty over long-term project pipeline and resulting utilisation and retention of staff	<ul style="list-style-type: none"> • Bidding in consortia • Research markets and requirements and build relationships to optimise positioning in a market 	High	<ul style="list-style-type: none"> • n/a 	n/a
Increasing cost reduction pressure under competitive auctions / lower tariff levels	<ul style="list-style-type: none"> • Bring contractors into consortium / risk/reward sharing with contractors • Innovative technologies to reduce cost • Use of larger WTGs • Bidding for cluster sites to achieve economies of scales 	High	<ul style="list-style-type: none"> • Support R&D • Support evolution of design codes to mitigate overly conservative designs and enable cost reductions • Encourage sharing of industry knowledge and lessons learnt • Consideration of developers' risk levels, project scale and status of market to determine reasonable tariff levels / strike price • Enact a robust penalty regime under auctions to mitigate unrealistic tariff levels from bidders and cancellation post bid award 	Medium

Developer risk / impact	Developers' mitigants	Risk level post developer mitigation	Regulator's mitigants	Risk level post regulator mitigation
Potential limitations in project optimisation due to lack of involvement in development and permitting	<ul style="list-style-type: none"> Consider limitations in tariff setting 	Low	<ul style="list-style-type: none"> Enable optimisation through flexible permitting and PPA conditions 	Low
Risk of losing bid bond / penalties / loss of project after successful bid award	<ul style="list-style-type: none"> Apply good industry practice to execution planning Contingency Float for delays Risk sharing with contractors Appoint experienced construction management team and contractors 	Specific to regulatory framework design	<ul style="list-style-type: none"> Consult with industry stakeholders to ensure regulatory requirements are reasonable and regulatory risk is acceptable for funders 	Specific to regulatory framework design
Risk of non-performance/delay by the grid operator	<ul style="list-style-type: none"> Build float into contractor schedule for grid operator delays Put fall-back plans in place / auxiliary power supply to protect assets 	High	<ul style="list-style-type: none"> Enact penalty/incentive regime for grid operator non-performance/ delay 	Low
Project cost greater than budgeted at bidding stage (auction model)	<ul style="list-style-type: none"> Bring contractors into consortium / risk/reward sharing with contractors 	Medium	<ul style="list-style-type: none"> Assume (part of) the development risks to shorten time between bidding and FID and/or COD to reduce cost uncertainty for bidders 	Low

The analysis of regulatory frameworks in Section 3 demonstrates that there are also framework designs under which the tariff is secured through auction and development risks are still assumed by the developer (decentralised auction model). This is, for example, the case in the UK and leaves developers with the highest risk levels (developer assumes combined risks of the traditional and central auction model). To date decentralised auction models have only been applied in markets with an existing pipeline of (partially) developed projects. Stakeholder interviews confirmed that a key driver for the participation in the auctions for CfD in the UK is the development expenditure incurred to date which has left developers being willing to accept a lower margin on equity than they would without the risk of sunk development cost. Participation rates are likely to be different if a decentralised auction regime was applied in an environment without a developed pipeline. As such the success of developers and/or regulatory frameworks does not only depend on the current regulatory frameworks but also on previous frameworks applied since the launch of development of a project and the transition mechanisms from one to another framework.

5.3.2 Funding risks

Funding risk is largely driven by the market environment. Stakeholder interviews confirmed growing trust in the industry and access to capital is not a bottleneck in the current market environment contrary to industry projections a few years ago. However, to secure funders trust, developers are required to demonstrate robust project planning and risk mitigation. Table 23 sets out risk mitigation strategies for funding risks.

Table 23. Risk mitigation strategies for funding risks

Possible developer risks	Developers' mitigants	Risk level post developer mitigation	Regulator's mitigants	Risk level post regulator mitigation
Inability to attract sufficient finance for relevant project	<ul style="list-style-type: none"> Obtain comprehensive financial, technical, legal and insurance advice to ensure project is developed to standards of target investors Allow sufficient time for due diligence process and FID by investors considering growing project size, hence investment volume and number of funders required. 	Low	<ul style="list-style-type: none"> Provide low interest funding from development banks where there are gaps in market funding and/or to promote innovative technologies. Provide lender-friendly tariff support (higher support for period of loan) 	Low
Risk of delay in funders' approval and resulting project delays	<ul style="list-style-type: none"> Consider experience of the targeted funders in the sector and allow appropriate timescales depending on the experience and number of funders required Seek to confirm particular requirements of each funder early in the process 	Medium	<ul style="list-style-type: none"> n/a 	

5.3.3 Construction risks

The construction phase is the part of the project lifecycle where expenditures and impact of risks, if not adequately mitigated, is greatest. .

Table 24 outlines the key construction risks and risk mitigation strategies. The main risk mitigation tool developers apply is to pass on risks to construction contractors. As passing on risks to contractors comes at a cost, developers will have to find a risk-reward balance of risks passed on to contractors and risks retained by the project. An example is the allocation of weather risks under construction (and operation contracts) as outlined in Box 32: Trends in weather risk allocation and risk mitigation strategies.

Table 24. Risk mitigation strategies for construction risks

Risk	Developers' mitigants	Post mitigation risk level	Regulator's mitigants	Post mitigation risk level
Planning Risks				
Capability of project team crucial to project success	<ul style="list-style-type: none"> Maintain a good industry network and strong retention policy Do not proceed through decision gates without an appropriate team 	Medium	<ul style="list-style-type: none"> As above 	Medium
Capability of contractors crucial to project success	<ul style="list-style-type: none"> Maintain a good industry network Currently a reasonably competitive market in most areas with some new entrants e.g. Asian companies moving into foundation manufacture Due diligence into experience and performance of staff within contractor team and right to replace staff reserved in Contract 	Medium	<ul style="list-style-type: none"> Establish stable regulatory regimes worldwide to support the sector, allowing greater industry investment in training, re-skilling and research Provide support for businesses with transferrable skills to move into the offshore wind industry, including Tier 2 and 3 suppliers, increasing competition throughout the supply chain 	Medium
Construction cost overrun, including materials and services	<ul style="list-style-type: none"> Construction contingency to deal with cost overrun Robust construction contracts Experienced contractors and project management team Float in construction schedule 	Low/ Medium	<ul style="list-style-type: none"> Clear and reasonable construction milestone requirements drafted in consultation with industry 	Low/ Medium
Foundation design requirements greater than estimated in tender phase leading to material costs or delays	<ul style="list-style-type: none"> Best practise is to complete and certify foundation design prior to final investment decision/financial close Support research and development into new foundation design techniques 	Low	<ul style="list-style-type: none"> Support research and development into new foundation design techniques, aimed at producing standardised foundation designs for a range of turbine types and soil conditions 	Low
Poorly defined interfaces lead to cost overruns - scope	<ul style="list-style-type: none"> Robust contract development with strong communication between different Package Manager Sign an Interface Matrix into all contracts, clearly specifying which contractor will perform which role in what area Independent contract review 	Low/ Medium	N/A	N/A

Risk	Developers' mitigants	Post mitigation risk level	Regulator's mitigants	Post mitigation risk level
Misunderstanding permitting requirements leads to material costs or delays	<ul style="list-style-type: none"> Maintain good relationship with authorities Permitting requirements can be substantial. Ensure all are thoroughly documented and contractor' requirements are passed to these companies Robust analysis of implications of permitting conditions. Generally, most have been manageable but some, such as piling restrictions if multiple projects are piling in the German North Sea, have potential for material impacts Generally, E&S impacts of offshore wind farms can be mitigated, with some positive effects identified 	Low	<ul style="list-style-type: none"> Regular analysis of conditions imposed on offshore wind farm throughout their permit suite to identify whether any requirements can be removed, refined or strengthened Build capacity within regulatory authorities to ensure authorities provide clear, unambiguous permit conditions Regular analysis of subsidy and permitting systems to ensure systems are simple, clear and consistent 	Low
Challenges obtaining permits lead to material costs, delays or potentially inability to permit projects	<ul style="list-style-type: none"> Develop projects in countries with supportive regulatory environments Comprehensive and transparent stakeholder engagement from earliest stage of project development Ensure Environmental Impact Assessment meets Equator Principle standards Support research into environmental and social impacts of offshore wind projects, including new mitigation strategies 	Low	<ul style="list-style-type: none"> Support research into environmental and social impacts of offshore wind projects, including new mitigation strategies 	Low
Delay Risks				
Contractor and subcontractor bankruptcy leads to substantial project delays	<ul style="list-style-type: none"> Robust analysis of financial strength of contractors and subcontractors prior to FID Require use of multiple subcontractors in critical areas e.g. foundation and cable supply Other legal/financial mitigants such as contractor securities, timing of transfer of title 	Low/ Medium	N/A	N/A
Delays to grid connection or other third party works lead to project level delays	<ul style="list-style-type: none"> Understand all sources of potential third party delay, particularly those not backed by delay LDs, and add appropriate float to construction schedule 	Low/ Medium	<ul style="list-style-type: none"> Provide commercial mitigation for developers and/or penalty to grid operator in the event of grid connection delays 	Low

Risk	Developers' mitigants	Post mitigation risk level	Regulator's mitigants	Post mitigation risk level
Delay risks (general) due to multi-contract strategy, contractor, third party or weather delay	<ul style="list-style-type: none"> • Robust contract development with strong communication between different Package Managers • Ensure project schedule and contract schedules are aligned • Provide reasonable float between contractual packages • Ensure allocation of weather risk is clearly specified in contracts and accurately captured in the project schedule • Procure weather measurement equipment at site to confirm weather downtime is attributed according to contractual arrangements • Design schedule and contracts so winter period can be used to catch up delays if necessary 	Medium	<ul style="list-style-type: none"> • Provide some flexibility in subsidy mechanisms so that developers are not penalised in the event of unseasonably poor weather • Support research and development into new installation techniques which are less weather sensitive 	N/A
Manufacturing delays lead to material impacts at project level	<ul style="list-style-type: none"> • Design a robust project schedule which can absorb a reasonable level of manufacturing delay • Robust due diligence of ability of suppliers to deliver, considering other industry commitments • Careful monitoring of progress at owner level to identify issues early so risks can be mitigated effectively 	Low/ Medium	<ul style="list-style-type: none"> • Provide support for businesses with transferrable skills to move into the offshore wind industry, including Tier 2 and 3 suppliers, increasing competition and capacity throughout the supply chain • Support research and development into new manufacturing techniques including standardisation to reduce delay risk 	Low/ Medium

Risk	Developers' mitigants	Post mitigation risk level	Regulator's mitigants	Post mitigation risk level
<p>Vessel and other major equipment availability and performance not as expected leading to delays, costs or Quality, Health, Safety and Environment (QHSE) risks</p>	<ul style="list-style-type: none"> • Design a conservative and robust project schedule • Ensure access to alternate vessels in the event of delay scenarios • Robust due diligence into commitments of supply and installation contractors and their vessels • If using a new-build vessel, ensure sufficient float prior to the date the vessel is needed on-site to manage construction or commissioning delays • Robust owner investigation of vessel performance and installation method statements, particularly for new WTG units • Early consultation of Marine Warranty Surveyor (MWS) to confirm suitability of vessels and MWS approval 	Low/ Medium	<ul style="list-style-type: none"> • Support research and development into new installation techniques and/or vessel designs 	Low/ Medium
Quality Risks				
<p>Poor cable handling and/or installation leading to cable failures. It is noted that approximately 80% of insurance claims paid out in offshore wind relate to cables</p>	<ul style="list-style-type: none"> • Use of strong supply and installation contractors • Strong owner supervision of installation and testing • Install cable integrity monitoring systems in array cables (typically these are just used in export cables) • Obtain appropriate lengths of spare cables and all associated accessories • Procure comprehensive insurance • Robust testing at handover from supply to installation (sub)contractor • Use of redundant sections in array and export cable networks 	Medium	<ul style="list-style-type: none"> • Support research into improved cable installation techniques • Support research into manufacture of cables and jointing systems that allow a greater level of redundancy, for example the ability to install sections of cable between array strings, in a low risk and cost-effective manner 	Low

Risk	Developers' mitigants	Post mitigation risk level	Regulator's mitigants	Post mitigation risk level
<p>Drive to reduce costs leading to choice of higher risks solutions with limited track records e.g. larger WTGs, new foundation designs, high voltage cables</p>	<ul style="list-style-type: none"> • Use of more established technologies. However, this may be challenging to achieve in markets driven by auction processes or if using floating technology • Robust due diligence of technology e.g. extent of testing, certification, operational performance • Pass technology risk to suppliers through supply and O&M contract warranties 	Medium	<ul style="list-style-type: none"> • Ensure cost reduction targets are achievable within a sustainable risk tolerance • Support research and development into new technologies to allow successful cost reduction • Support development and evolution of international technical standards for all mature aspects of the offshore wind industry 	Low
<p>Poor quality ground studies provided to contractors lead to material additional costs, delays or performance impacts in construction or operations</p>	<ul style="list-style-type: none"> • Complete comprehensive studies before/during tendering, ensuring an appropriate budget available for what is likely to be a major expense • Support research and development into new ground investigation technologies, particularly sub-surface scanning techniques 	Medium	<ul style="list-style-type: none"> • In either an auction or strategic site allocation process, regulators could perform bankable ground investigation studies at their cost to ensure sites provided to developers are appropriate for offshore wind development. A staged investigation approach should be used to rule out inappropriate sites. • Support research and development into new ground investigation technologies, particularly sub-surface scanning techniques. 	Medium
<p>Skills shortage in industry</p>	<ul style="list-style-type: none"> • Potential for oil and gas experience to become more affordable as a result of currently low oil prices, although not all oil and gas experience is directly transferrable to offshore wind • Invest in staff training over the medium term 	Medium	<ul style="list-style-type: none"> • Establish stable regulatory regimes worldwide to support the sector, allowing greater industry investment in training, re-skilling and research • Support training courses and university programmes specialising in the offshore wind sector 	Low/ Medium

Risk	Developers' mitigants	Post mitigation risk level	Regulator's mitigants	Post mitigation risk level
Poor quality control leads to suboptimal project being delivered	<ul style="list-style-type: none"> • Use of strong contractors • Appreciate that regardless of contractor strength, experience of industry is that owner management is crucial • Owner Quality Assurance (QA) Plan should envisage inspection of all facilities and owner presence potentially including use of full-time supervision in challenging sites. An appropriate budget should be provided for a substantial staffing level 	Low/ Medium	<ul style="list-style-type: none"> • N/A 	N/A

Box 32: Trends in weather risk allocation and risk mitigation strategies

Initially, as a result of the lack of experience within the offshore wind supply chain, contractors were reluctant to take weather risk or offered to assume the risk at a material premium. Developers assumed very different strategies. Utilities tended to assume all weather risk and dealt with it by allowing float in the construction schedule and paying contractors for additional cost due to weather downtime. IPPs on the other hand were facing lenders with no experience in the sector who were unwilling to assume weather risk. As such, some IPPs passed on all weather risk to the contractors at a material premium.

Over the years and with maturing industry, weather and safe working limits of the different works are better understood and site weather risk can be determined based on long-term historic data. As such, there has been a trend among utility and IPP developers towards sharing the weather risk with the contractor and introducing incentives for the contractor to optimise its planning to minimise weather downtime risk. This approach has resulted in lower contractor margins.

5.3.4 Operational risks

Operation risks are influenced by the industry and the market environment in general and largely controlled by the developer through risk allocation under operation and maintenance contractors. Regulators have no explicit impact or influence on operation risks but can act as enabler to support continued development of the industry. Table 25 outlines the key operation risks and risk mitigation strategies that can be applied by developers and regulators. An example of industry learning and evolution of risk mitigation strategies is provided in Box 33: Evolution of risk mitigation strategies of non-accessibility for maintenance.

Table 25. Risk mitigation strategies for operation risks

Risk / challenge	Developers' mitigants	Post mitigation risk level	Regulator's mitigants	Post mitigation risk level
Identification of experienced contractors and deployment of experienced contractor teams	<ul style="list-style-type: none"> • Currently strong reliance on OEMs and utility developers performing O&M • Third party O&M provider entering the market • Maintain a strong industry network • Definition of minimum training/seniority requirements for key staff under O&M contracts 	Medium	<ul style="list-style-type: none"> • Establish stable regulatory regimes worldwide to support the sector, allowing greater industry investment in training, re-skilling, and research • Provide support for businesses with transferrable skills to move into the offshore wind industry, including Tier 2 and 3 suppliers, increasing competition throughout the supply chain 	Medium
Drive to reduce costs leading to choice of higher risks solutions with limited track records e.g. larger WTGs, new foundation designs, high voltage cables	<ul style="list-style-type: none"> • Use of experienced O&M Contractors • Robust due diligence of technology e.g. extent of testing, certification, operational performance • Pass technology risk to suppliers through supply and O&M contract warranties 	Medium	<ul style="list-style-type: none"> • Support research and development into new technologies to allow successful cost reduction • Support development and evolution of international technical standards for all mature aspects of the offshore wind industry 	Low
Poor O&M Contract wording leads to cost over-runs or undermines strength of Availability Warranty	<ul style="list-style-type: none"> • Ensure any weather risk sharing clearly documented in Contract • Careful analysis of Availability Warranty provisions, ensuring these are accurately reflected in the financial model • Independent contract review 	Low	<ul style="list-style-type: none"> • N/A 	N/A
Insufficiently robust contractor management leads to cost over-runs, undermines strength of Availability Warranty or leads to QHSE issues	<ul style="list-style-type: none"> • Robust Contractor supervision including Owner site representatives, comprehensive analysis of SCADA availability data and ongoing performance analysis 	Low	<ul style="list-style-type: none"> • N/A 	N/A

Risk / challenge	Developers' mitigants	Post mitigation risk level	Regulator's mitigants	Post mitigation risk level
Poor quality energy yield assessment leads to lower than expected performance	<ul style="list-style-type: none"> • Robust measurement campaign • Use of robust energy yield methodology using the latest techniques • Obtain independent view on potential production • Support industry in developing new tools 	Low/ Medium	<ul style="list-style-type: none"> • In either an auction or strategic site allocation process, regulators to perform bankable wind measurement campaigns and/or energy yield studies to ensure developers have sufficient information to value their projects appropriately. • Provide funding to install meteorological masts capable of generating bankable wind data, which can be used for sites a relatively large distance from the masts. • Support industry in developing R&D and commercialisation of new tools such as floating LiDAR. 	Low/ Medium
Poor understanding of site accessibility leads to performance below expectations	<ul style="list-style-type: none"> • Develop comprehensive operational accessibility study pre-FID to quantify risk in this area • Consider the use of mitigating technologies such as helicopters, hotel vessels and new access concepts 	Low	<ul style="list-style-type: none"> • Support research into improved access concepts 	Low
Slow response in major interventions	<ul style="list-style-type: none"> • Negotiate strongest availability warranty possible with O&M Contractor • Possibility to take over O&M as developer, however assure transition period, training by and support from OEM until robust capabilities have been built 	Medium	<ul style="list-style-type: none"> • Support research into improved major intervention techniques including vessels. • Support training courses and university programmes specialising in the offshore wind sector. • Provide support for businesses with transferrable skills to move into the offshore wind industry, including Tier 2 and 3 suppliers, increasing competition throughout the supply chain 	Low
Poor end of warranty inspections means issues that should have been addressed by supply contractors are not addressed	<ul style="list-style-type: none"> • Develop a comprehensive end of warranty inspection program and deliver well in advance of warranty expiry. 	Low	<ul style="list-style-type: none"> • Support research into improved inspection techniques such as use of drones and robots. 	Low

Risk / challenge	Developers’ mitigants	Post mitigation risk level	Regulator’s mitigants	Post mitigation risk level
Health and safety risk	<ul style="list-style-type: none"> Ensure all staff have appropriate training. Instil commitment to HSSE throughout supply chain – incentives for near miss and hazardous observation reporting. Strong owner analysis of method statements and risk assessments, plus strong owner presence particularly in high risk areas 	Medium	<ul style="list-style-type: none"> Build capacity within regulatory authorities, increasing support to developers and contractors in delivering robust HSSE management 	Medium
Risk of offtaker or grid operator not accepting energy	<ul style="list-style-type: none"> Clarify grid code and testing requirements and pass on to construction and operation contractors. Budget for residual grid downtime and/or curtailment risk. 	Low	<ul style="list-style-type: none"> Grant priority of dispatch to offshore wind farm operators 	Low

Box 33: Evolution of risk mitigation strategies of non-accessibility for maintenance

A key differentiator of offshore wind projects compared to onshore wind projects is the risk of non-accessibility, which can materially increase the downtime and cost impact of a technical fault. This risk is typically accounted for within the developers’ business case and underlying availability assumptions based on long-term weather data. For the first wind farms that entered into operation WTGs were typically accessed using crew transfer vessels (CTVs) with an operating limit of 1.5m significant wave height. Crews would return to the onshore harbour at the end of the working day and, as such, effective working hours are reduced by the time required to travel to and from the site.

With the industry moving towards larger sites further offshore, accessibility strategies have evolved to reduce the risk of non-accessibility. This includes the use of onsite hotel vessels on which technicians are able to stay onsite overnight, eliminating travel time and increasing effective working hours. The use of hotel vessels may be combined with hydraulic access systems, such as Ampelmann, that can work in more adverse weather conditions than CTVs. Whilst these strategies reduce the risk of non-accessibility, they come at a cost and are generally only viable for larger scale projects further offshore.

5.4 TRENDS IN DEVELOPER RISK PROFILES AND DRIVERS

Table 26 outlines the trends in how developer risk profiles are evolving and the key drivers. It shows that the introduction of auctions in the European offshore wind market has materially changed the risk profile and scope of developers.

Table 26. General trends in developers' risk levels

Project risk category	Trends in developer risk level	Drivers
Allocation risk		<ul style="list-style-type: none"> • Introduction of auctions and cap on market growth • Trend towards “central model” with site selection by regulator and cap on market growth rate • High levels of competition under auctions to date • Uncertainty over timing and size of auction rounds • Need for differentiated support for innovative technologies
Price Risk		<ul style="list-style-type: none"> • Competitive auctions create strike price uncertainty. • Wholesale price uncertainty. • Commodity price volatility.
Development risk		<ul style="list-style-type: none"> • Trend of regulators assuming part or majority of the development scope to derisk project for developers, increase chance of project realisation and to meet policy targets. • Increasing project size and scale of overall industry requires coordinated approach to grid connection.
Funding risk		<ul style="list-style-type: none"> • Increasing trust by funders • Attraction of new funders to the market • Increase in project size requires greater number of funders per project
Construction risk		<ul style="list-style-type: none"> • Learning of the industry • Greater trust in contractor capabilities • Greater availability and competition of contractors • Continued evolution of technologies and use of technologies with limited track record • Sites conditions become more challenging (deeper waters, further offshore, larger capacity and larger equipment) • Increasing cost reduction pressure due to lower tariff levels
Operation risk		<ul style="list-style-type: none"> • Learning of the industry • Greater trust in contractor capabilities • Greater availability and competition of contractors • Limited track record of aging assets • Sites conditions become more challenging (deeper waters, further offshore) • Increasing cost reduction pressure due to lower tariff levels
		 Decreasing  No clear trend/mixed drivers  Increasing

With the introduction of auctions to allocate rights to develop, construct and operate offshore wind farms, developers' risk of securing such rights has increased and with it introduced uncertainty for developers over the location, size and nature of their project pipeline. In order to increase the chances of winning a bid, spread the risks and enable participation in a greater number of bids, there is a trend of bidding in consortia, including the big utility players.

Auctions introduced a cap on market growth which has led to a consolidation in greater levels of collaboration in the market. For example, utility developers such as Centrica and Statkraft announced their exit from the offshore wind market. Stakeholder interviews indicate that the consolidation provides greater comfort in the market for the remaining players. However, the participation rates in the European 2016 auctions suggest that the allocation risk for developers remains high.

Once a bid is won, the development and grid connection risk assumed by the developer tends to be lower than under traditional pre-auction regimes as the regulator assumes part or the majority of these risks through development prior to tender award to developers. This shift in risk allocation is driven largely by the regulators as country markets tend to be comprised of a small number of projects with a large scale. As such, the impact of failure of a single project on policy targets is relatively high. With regulators assuming parts of development and grid connection risks they are reducing the risk of a project cancellation after bid award.

Stakeholder interviews confirmed that there are developers in the market with the capability and willingness to assume greater development and grid connection responsibilities provided rewards reflect such greater developer risk.

Several interviewees pointed to developments in the relationships between developers and the supply chain, stating that there has been increased collaboration in recent years. One developer observed benefits to working with both WTG suppliers and electrical infrastructure suppliers to optimise the design of a project to reduce the cost of the whole project, rather than just their contracts. Collaboration through the supply chain is also seen as having potential for further cost reduction.

Interviewees also expressed concern that, while the new auction regime increases competition and appears to drive down costs, there is a potential to put too much pressure on the supply chain, which may not be sustainable. This is an observation that is also shared by WindEurope. Developer strategies to achieve the required cost reductions are yet to be confirmed, however, it is expected that the use of larger WTGs will play a key part in driving down cost.

As outlined throughout our analysis, auction regimes with decentralised site selection have only been applied in markets with an existing pipeline of developed projects. Under centralised auction regimes, the regulator pre-selects sites and undertakes at least partial development of sites which reduces developer scope and risk and subsequently tariff levels. When considering a centralised auction model, regulators should assess whether they have the capabilities to deliver such a role in a cost effective and timely manner.

5.5 LESSONS LEARNED

Allocation and price risks are increasing due to recent regulatory changes

While the recent falls in prices can be attributed, at least in part, to the move to competitive tenders and centralisation of project development, regulatory risks have increased for developers. Developers now have to compete on price against each other to secure power purchase agreements, raising the risk of lower prices and of the project not going ahead.

Technical risks, including construction and operation, are decreasing

Experience with increasing cumulative capacity, together with a strengthened industry structure, is reducing perceived technical risks, both in construction and operational phases. However, more challenging site conditions, larger equipment requirements and larger projects, combined with increasing cost pressures, present future challenges.

Regulatory risk is a major contributor to the overall risk for an offshore wind project

While offshore wind projects are technically challenging, over the recent year the supply chain has matured, and project developers have grown in experience to the extent that the technical risks are known and can be effectively mitigated. Risks relating to possible regulatory changes, poor medium term visibility of tenders and uncertainty around long term strategies present the greatest risks to developers and the supply chain.

Developers don't require all risks to be mitigated, but regulatory frameworks need to ensure a suitable risk-reward balance for developers

Developers are willing to assume risks they can control such as development risks or the construction of the grid connection, provided rewards are reasonable. Policy makers should consider the costs and benefits the impacts of assuming the development risks.

Allocation of risks to third parties requires effective third party performance incentives

Well-meaning regulators have passed on grid connection risk to grid operators with the aim to reduce developer risk and attract developers to the market. Experience has shown that in order for such strategy to be successful the following needs to be fulfilled:

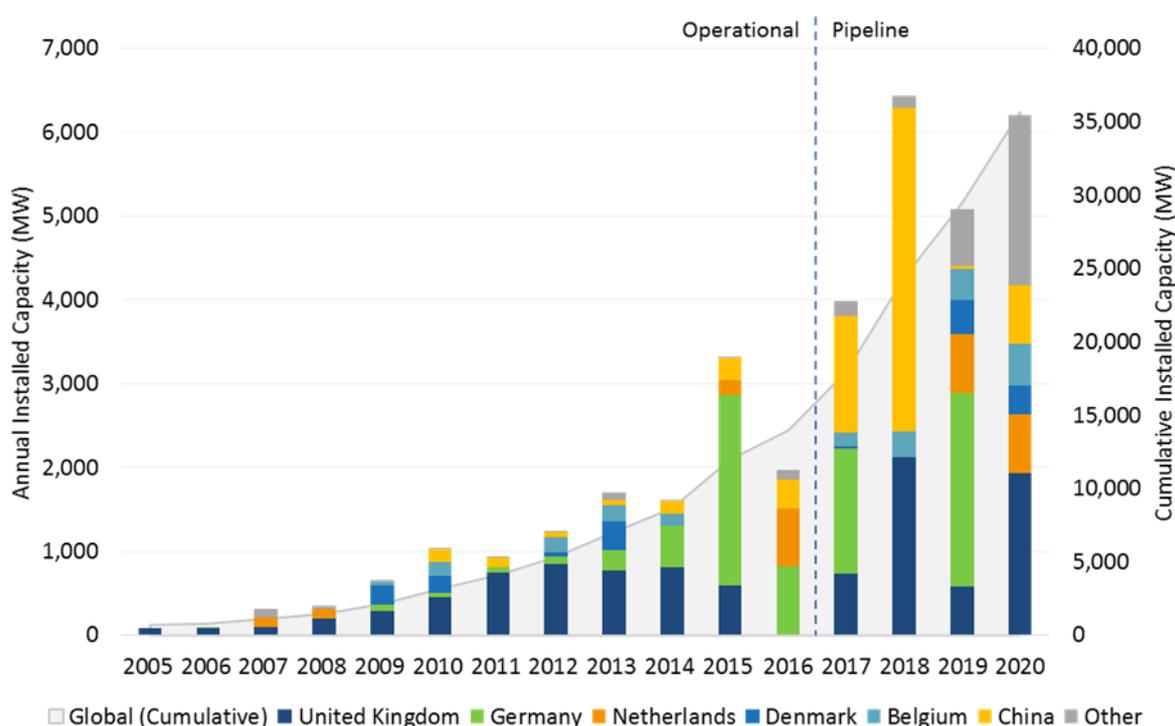
- Grid operator to have the capabilities to assume the risks.
- Grid operator is subject to effective performance incentives / penalty regimes that provide developers with confidence that poor performance of the grid operator is mitigated.

6 SYNTHESIS, CONCLUSIONS, AND RECOMMENDATIONS

6.1 STATE OF THE INDUSTRY

Offshore wind is a rapidly maturing energy technology which can offer multiple benefits to policy makers wanting to decarbonise the electricity system at low cost and with significant local economic benefits. Following several years of technology proving and steadily increasing deployment, the industry is entering a period of maturation and exponential growth, with global installed capacity set to increase by >150% from 14.4 GW at the end of 2016 to 36.2 GW by 2020. Having been pioneered by a handful of leading European countries, offshore wind is also expanding to a number of emerging markets in Asia and North America.

Figure 27. Annual and cumulative offshore wind installed capacity



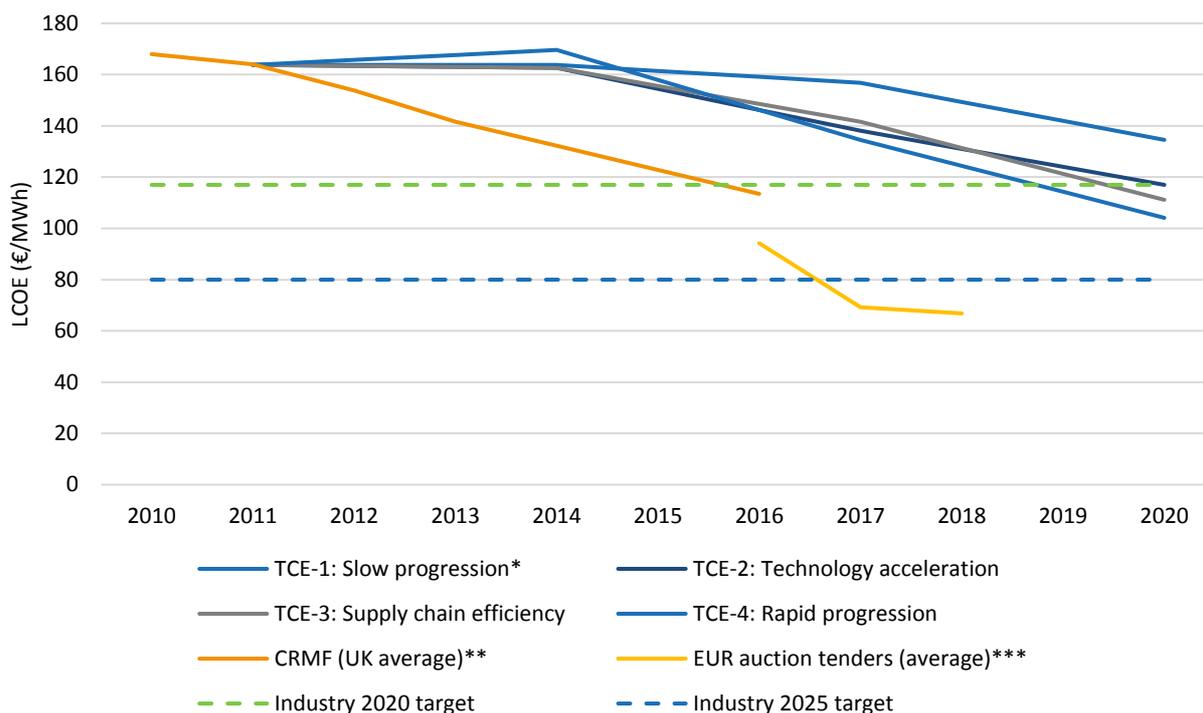
Sources: 4Coffshore, 2017; WindEurope, 2017; Carbon Trust analysis⁶²

The growing maturity of the sector is particularly evident in the steep cost reduction achieved in recent years, which has far exceeded industry projections and targets. In particular, the introduction of competitive auctions has seen an acceleration in the pace of cost reduction in several front-runner markets. Recent contract awards place the cost of new offshore wind capacity well below the 2025 target of €80/MWh, 8 years ahead of schedule, with projects in Denmark and the Netherlands entering FID in 2017-2018 attaining strike prices equivalent to below €70/MWh⁶³. This marks a reduction of 60% from 2010 levels.

⁶² Pipeline data is based on a central scenario of deployment, according to probability of project build.

⁶³ Borssele III & IV tender achieved a strike price of €54/MWh, equivalent to ~€68/MWh once a €14/MWh uplift is applied to account for grid connection and site development costs.

Figure 28. Offshore wind cost trends in Europe



* The Crown Estate (TCE) Cost Reduction Pathways (2011); ** Cost Reduction Monitoring Framework (2017)
 *** Includes grid connection and site development costs for NL and DK projects (uplift of €14/MWh⁶⁴). It should be noted that many of the ‘actual’ projects reaching FID have not yet been built.

The cost reduction achieved has been driven by several factors, including: considerable technology innovation, particularly larger turbines; scale effects through increasing project size, clustering, and cumulative installed capacity; increased competition throughout a more mature supply chain; greater experience and capability through learning by doing; preferential financing terms from a more diverse range of investors viewing offshore wind as a bankable asset class and an attractive investment opportunity; and increased government intervention to de-risk projects for developers. Many of these drivers are expected to continue driving down costs over the coming years as offshore wind establishes itself as a vital component of the energy system for many countries in Europe and further afield.

⁶⁴ €14/MWh derived from €12-15/MWh range suggested by NERA Consulting (2016) *Auctions and Bidding Strategy for Offshore Wind*, available at http://www.nera.com/content/dam/nera/publications/2016/PUB_Offshore_Wind_A4_0916.pdf and €14/MWh used by BVG Associates in <http://www.offshorewind.biz/2016/10/28/borssele-tender-revealed/>

6.2 POLICY & REGULATION

The deployment, technology innovation and cost reduction achieved to date have been underpinned by supportive policy frameworks across several front-runner markets. This study has assessed the efficacy and evolution of government policy in leading offshore wind jurisdictions, evaluating policy measures across six key pillars: market scale and visibility; site development; grid connection; incentive mechanisms; supply chain development; and innovation support. In particular, two significant policy trends are discussed: the transition to competitive auction-based systems and the transition to more centralised development models.

MARKET SCALE & VISIBILITY is consistently considered the most critical driver for offshore wind development, giving confidence to developers and suppliers to plan and make necessary investment decisions ahead of time. Key findings include:

- Offshore wind policy objectives should form part of a country's long-term energy strategy
- Visibility is needed over long time horizons
- Ambitious targets can catalyse the industry, but need to be integrated within, and supported by, the wider policy framework
- Short to medium-term roadmaps can hedge against long-term uncertainty
- Stakeholder engagement can support buy-in and longevity for national deployment strategies

SITE DEVELOPMENT models vary across jurisdictions, characterised by the allocation of development activities between government bodies and wind farm developers. Centralised models can be effective in de-risking sites for developers, but must be balanced with ensuring that risks and responsibilities are handled by the most competent bodies. Key findings include:

- Spatial planning is critical to selecting the best development zones and mitigating consenting challenges
- Centralised site-specific development can reduce up-front cost and risk for developers, but may not result in selection of the best sites
- Consenting regimes should provide a clear framework with defined timelines, coordinated responsibilities, and front-ended consultation
- 'One-stop-shop' entities that bundle permits into a single process can streamline the permitting process and mitigate stakeholder conflicts
- Greater flexibility in the consenting envelope can future-proof sites for the adoption of innovative, low cost technologies
- Site extensions could be a cost-effective and low risk means of deploying additional offshore wind capacity
- Scientific research studies can be used to inform and improve consenting processes
- Cumulative impacts are an increasingly important issue for the industry

GRID CONNECTION is a critical element of offshore wind policy which can significantly impact on the risk profile and funding requirements for a given project. Grid policy is largely characterised by the differentiation of responsibility between developers, system operators, and third parties, in addition to regulation imposed by government grid regulators. Key finding include:

- Centralised TSO-build ('shallow charging') approaches can help with strategic coordination of power transmission to ease onshore grid constraints
- Decentralised developer-build ('deep charging') models can result in lower cost point-to-point transmission

transmission assets, but centralised TSO-build models may deliver net lower societal costs if offshore hubs and interconnection can be integrated

- TSOs need to be sufficiently capitalised to take on the cost and risk of managing all transmission assets
- Suitable liability clauses need to be in place to reduce the risk profile for wind farm developers and transmission operators
- Standardisation and innovation can deliver considerable cost reduction

INCENTIVE MECHANISMS are critical enablers for offshore wind deployment. Incentive mechanisms have evolved as the sector and technology have matured, from grants and feed-in tariffs in the industry's formative years to more market-based mechanisms today, including the recent adoption of competitive auction systems. Key findings include:

- Various incentive mechanism design options are available to policy makers, which balance risk between government and developers
- Governments must balance low costs with the risk of non-delivery
- Beyond mechanism design, the most important factor is providing clarity, visibility, and stability
- Transitions from fixed-remuneration systems to competitive auctions can introduce higher allocation and price risk and need to be managed carefully
- Emerging markets should carefully consider when to adopt competitive auction systems
- Ability to adopt competitive approach depends on domestic capabilities
- Competitive auctions should be designed to deter speculative bids and penalise non-delivery

SUPPLY CHAIN DEVELOPMENT is vital to build the necessary capability to deliver projects on time and on budget, as well as improve the competitiveness of domestic suppliers. Linking energy policy to industrial strategy can maximise the capture of local economic benefits, but local content objectives will need to be balanced with cost reduction goals. Key findings include:

- Suppliers need long-term visibility and certainty of market scale
- Local content requirements can support domestic industrial policy, but are likely to be a barrier to cost reduction
- Bottom-up initiatives may be more effective in balancing government objectives to reduce costs and maximise local economic benefit
- Public investment in infrastructure can catalyse private sector investment, leading to the creation of supply chain clusters
- Business support programmes can attract new market entrants and improve supplier competitiveness
- Specialisation, through leveraging existing capabilities and investing in innovation, can create competitive advantage for domestic suppliers
- While Europe has been relatively insulated from supply chain bottlenecks due to cumulative market scale and regional cooperation, isolated emerging markets (e.g. USA, Japan, Chinese Taipei) with limited market size will face greater challenges
- International and inter-state cooperation can remove entry barriers for emerging markets

INNOVATION SUPPORT is essential to complement supply chain policies and drive cost reduction across the industry. Technology innovation has been a cornerstone of cost reduction achieved to date and will continue to play a major role going forward. Key findings include:

- Strategic identification and prioritisation of technology innovation needs can focus R&D efforts
- Creating close ties between academic research centres and industry can maximise market penetration of novel technologies
- Industry-led collaborative R&D programmes can maximise the impact of public and private funding
- Involving financial institutions and lending advisers early in the R&D process can mitigate high risk perception of new technologies
- Policies should be designed to enable integration of technology demonstrations in commercial projects
- A balance of innovation support should be maintained across technology readiness levels

Emergent policy trends

While policy change can be disruptive to investor confidence, a certain degree of policy evolution is necessary in order to adapt to prevailing market conditions and growing technology maturity, as well as capture and implement best practice learnings. At present, two key emergent trends are apparent:

1. Transition to competitive auctions

With offshore wind maturing as an energy technology and with increasing pressure to drive down costs, competitive auctions have been introduced in several countries. Recent auction tenders suggest that this approach has been effective in delivering steep cost reduction, but capacity constrained auctions have also increased price and allocation risk for developers.

It is expected that many countries will be able to move directly to competitive auction-based systems. However, this approach may increase the risk of non-delivery, particularly if a country lacks access to a robust supply chain. More isolated markets are therefore expected to adopt fixed remuneration support systems, such as feed-in tariffs, to stimulate local industry before introducing greater price competition.

2. Transition to centralised development models

To balance increasing price and allocation risk for developers from capacity constrained and competitive auctions, as well as manage onshore grid constraints, several governments are taking on greater up-front risk in the development stage. Development de-risking activities, such as obtaining consent, acquiring site data, and securing grid permits, can limit the risk exposure for prospective developers who would otherwise need to invest tens of considerable sums in undertaking these activities without any guarantee of ultimately succeeding. As a consequence, there has been shift from typical open door approaches to site-specific tendering, often with the provision of offshore transmission assets (for example in Denmark, the Netherlands, and Germany).

However, it should be noted that, to be delivered effectively, centralised approaches require considerable capacity building within government departments and relevant third parties, such as transmission system operators, as well as suitable regulation to balance the risk profile for relevant parties. Indeed, wind farm developers often exhibit a preference for greater control of many development activities and offshore transmission assets. This is partly based on a perception of greater efficiency from developers compared to government bodies, a desire to be able to demonstrate competitiveness across a wider scope of activities, and also heightened portfolio risk from widespread adoption of site-specific tendering.

Aligning policies with government objectives

This report highlights a large number of best practice policy measures for offshore wind development. However, the specific policies adopted by governments will be highly contingent on both local context and national objectives. Indeed, local context often defines the stated objectives of national governments. The inter-related nature of different policy measures often results in trade-offs for policy makers to consider. Thus, while governments may desire achieving multiple competing objectives, these are not always compatible. Table 27 provides an indicative example of policy approaches in order to achieve four common government objectives, highlighting the trade-offs that can exist.

Table 27. Indicative policy measures and prioritisation by government objective

		Government Objective			
		Catalyse deployment	Maximise cost reduction	Maximise local economic benefits	Alleviate onshore grid constraints
Policy Measure	Market scale & visibility	High deployment targets Long-term visibility	High deployment targets Long-term visibility	High deployment targets Long-term visibility	Constrained deployment Long-term visibility
	Site development	Site de-risking activities	Site de-risking activities	Site de-risking activities	Site-specific tendering
	Grid connection	<i>Country-specific</i>	<i>Country-specific</i>	<i>Country-specific</i>	Centralised coordination of transmission networks
	Incentive mechanism	Fixed remuneration support	Auction-based system	Local content within evaluation criteria	Capacity-constrained auctions
	Supply chain	Supply chain enabling policies	Innovation support; Maximise supplier competition	Infrastructure investment	Investment in grid infrastructure
	Innovation	Focus on high TRL	Balanced support across TRLs	Targeted support for areas of specialisation	Focus on system balancing/ interconnection

Key: Green = High emphasis; Amber = Moderate emphasis; Red = Low emphasis; Grey = Dependent on local context.

Catalyse deployment: Policy makers looking to catalyse deployment to meet decarbonisation and energy security goals should prioritise giving long-term visibility of market scale, combined with fixed remuneration support (e.g. feed-in tariff/premium). Particularly in more isolated emerging markets, providing guaranteed levels of fixed support can reduce revenue risk for developers and encourage new suppliers to enter the market. This should be complemented with targeted supply chain support programmes, tailored to local requirements and specialisations.

The risk of non-delivery might also be mitigated by government de-risking activities, such as the provision of pre-consented sites. However, policy makers will need to consider whether the level of internal capacity building required is feasible with high deployment volumes, or whether the cost and level of resources is justified if anticipated deployment levels are low.

Innovation support may be considered lower priority, but can be focussed towards higher TRL technologies that can be adopted in early projects. However, countries with long-term deployment aims are encouraged to maintain support for innovation across TRL levels. Countries may also need to support R&D activities to overcome specific local challenges, such as resistance to natural hazards.

Maximise cost reduction: Long-term visibility of market scale is equally important for policymakers prioritising cost reduction. As opposed to fixed remuneration support, the adoption of auction-based systems is likely to be more effective in driving down costs. Indeed, the recent shift to competitive auctions is largely driven by governments prioritising cost reduction as their primary objective.

However, the tighter margins can put pressure on suppliers and increase the risk of non-delivery if projects encounter issues or market forces lead to increased costs. Innovation is likely to be high priority across all TRL levels, creating a strong pipeline of low cost technology innovations. This may converge with supply chain support, however, countries with low consumer costs as a primary objective may be able to achieve cost reduction goals by leveraging non-domestic supply chains.

Maximise local economic benefits: Maximising local economic benefits and aligning energy policy with industrial strategy will require more targeted supply chain support, through a combination of investment in enabling infrastructure and support for domestic businesses. This can include a prioritisation to provide innovation support for companies with potential to service both domestic and overseas markets.

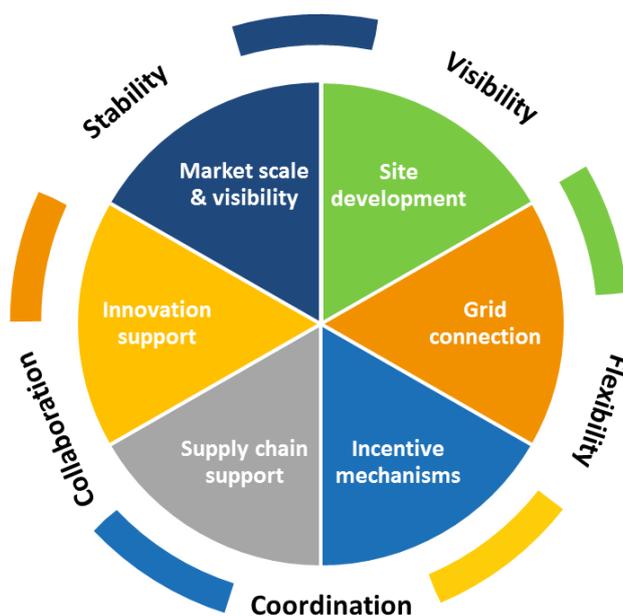
Local content requirements can also be introduced and tied to incentive mechanisms. Although this can be effective in ensuring supplier contracts are concentrated domestically, stringent requirements can be a barrier to achieving cost reduction goals.

Alleviate onshore grid constraints: For several countries, onshore grid constraints are a barrier to deploying large volumes of offshore wind. Policy makers may therefore look to control the amount and phasing of additional installed capacity. This is likely to be enabled through capacity constrained tenders for specific sites, under a centralised development model. A site-specific approach can enable government departments to manage connection points for new capacity and ensure that onshore grid reinforcements are coordinated to meet demand.

Key overarching principles

Despite the competing objectives and trade-offs that policy makers must consider, there are several key principles that should remain embedded in government policy in order to effectively achieve national goals and support offshore wind development:

Figure 29. Key principles and policy areas for effective offshore wind development



- **Stability:** Stability is vital to maintain trust between government and industry and ensure continuity in the sector. Retroactive changes to policy can be extremely damaging to investor confidence, leading to higher risk premiums and higher energy costs. A clear and transparent legal framework is essential, and any changes to policy should be communicated ahead of time and managed to limit damage to industry confidence.
- **Visibility:** Given the long development cycles for offshore wind farms, visibility is essential to enable developers, suppliers, and responsible authorities to plan and make necessary investment decisions. This can include visibility of long-term market scale (i.e. deployment targets, subsidy support budgets), the scale and timing of auction rounds, and the timeline and requirements for permitting and consenting procedures.
- **Flexibility:** Flexibility in regulatory regimes can maximise opportunities for wind farm developers to reduce project costs. This can include flexibility in consenting envelopes to enable the adoption of novel technologies, flexibility in site selection and layout, flexibility in the phasing of delivery milestones, and, depending on national objectives, flexibility in local content requirements.
- **Coordination:** Clear and coordinated responsibilities between government departments with shared objectives is vital to ensuring a smooth and efficient delivery of offshore wind programmes. One-stop-shop entities can be an effective means of ensuring coordination and maximising efficiency and clarity for wind farm developers. Consultation should also be expanded to all impacted stakeholders and front-ended to mitigate potential conflicts.
- **Collaboration:** Collaboration between governments and industry will be critical to delivering low cost offshore wind across geographies. Inter-governmental collaboration can foster greater interconnection, help to manage deployment schedules to avoid supply chain bottlenecks, and maximise consistency in consenting regulations. Meanwhile, collaboration across industry and government in innovation activities can maximise the impact of R&D spend and deliver lower cost technology solutions.

6.3 INDUSTRY STRUCTURES

The development of an offshore wind industry requires involvement from a range of players that make up the industry structure. As the sector has matured, these industry structures have evolved, with the number and type of active players, as well as the models and strategies pursued, changing over time. Key findings include:

- The industry has developed in recent years and may be entering a market maturation phase in key established markets such as the UK and Germany
- The market has been comprised of two distinct models: the utility and independent power producer developer (IPP) models
- Developer models have evolved, with growing use of project finance by utility developers, and a trend towards development consortia
- Predictions of capital constraints have not been borne out, due to slower pace of development and increasing trust by funders in the industry's capabilities
- Many emerging markets have significant supply chain capabilities due to pre-existing onshore wind and oil & gas industries. However, a lack of vessels for WTG installation and O&M servicing could present potential bottlenecks.

Industry maturity

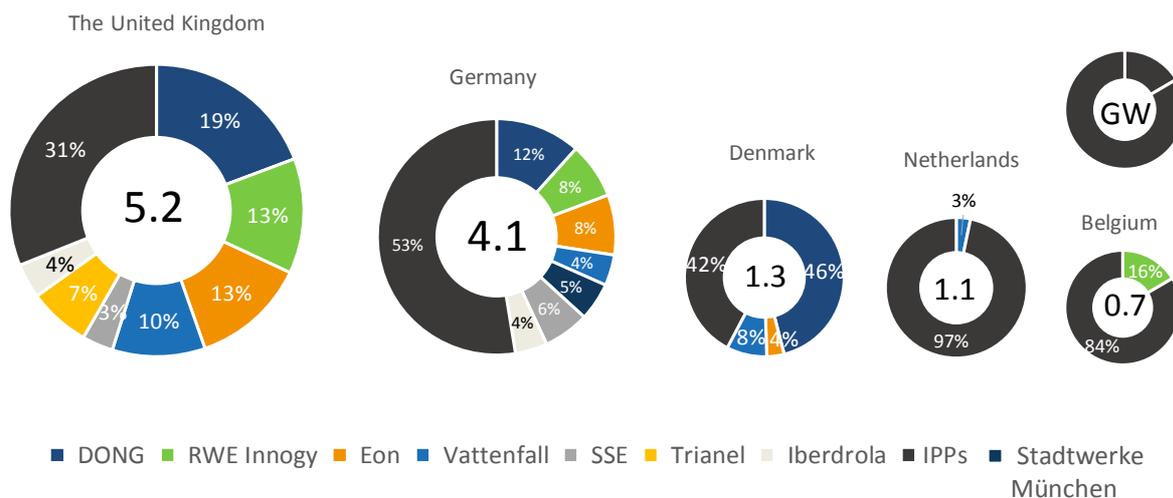
A growing body of evidence suggests that the offshore wind industry in the established markets of Northern Europe has matured in recent years. The industry has moved from innovation (1990 to 2001), adaptation (2002 to 2008), to market stabilization (2009 to 2015). The market stabilisation phase is marked by an increase in project size; the development of dedicated manufacturing facilities; and a supply chain distinguishing itself from the oil & gas and onshore wind industries. Evidence from the stakeholder interviews suggest further developments through the market stabilisation phase, suggesting that the industry may be moving into a 'market maturation' phase:

- Steep cost reduction evident in several European countries.
- Several European markets have become commoditised, with financial investors, commonwealth funds and pension funds now investing in operating assets, allowing utilities to recycle capital to new projects.
- Perceived risks from the investor and finance community have been reduced due to growing confidence in the ability of developers and the supply chain.
- Project margins have reduced over the last five years due to increased confidence in the industry and perceived reduction of residual risk levels.
- Consolidation of industry developers, particularly in the UK where significant exits have left fewer players in the market.

Project developers

There are two broad categories of developer model; the utility-developer and IPP-developer. While utility developers have tended to dominate in the UK and Denmark, IPP-developers have been more successful in Germany, Belgium and the Netherlands (see Figure 30). Historically, utility-developers have mostly relied on balance sheet financing with less third party scrutiny. This enabled them to adopt higher risk approaches, with more contracts and more aggressive scheduling. In contrast, IPP-developers tended to adopt risk adverse strategies, with a smaller number of construction contracts, conservative scheduling and technology choices to meet requirements of debt providers.

Figure 30: Market share of utility-developers in operating projects



Source: Mott MacDonald analysis, based on Wind Europe, 2016

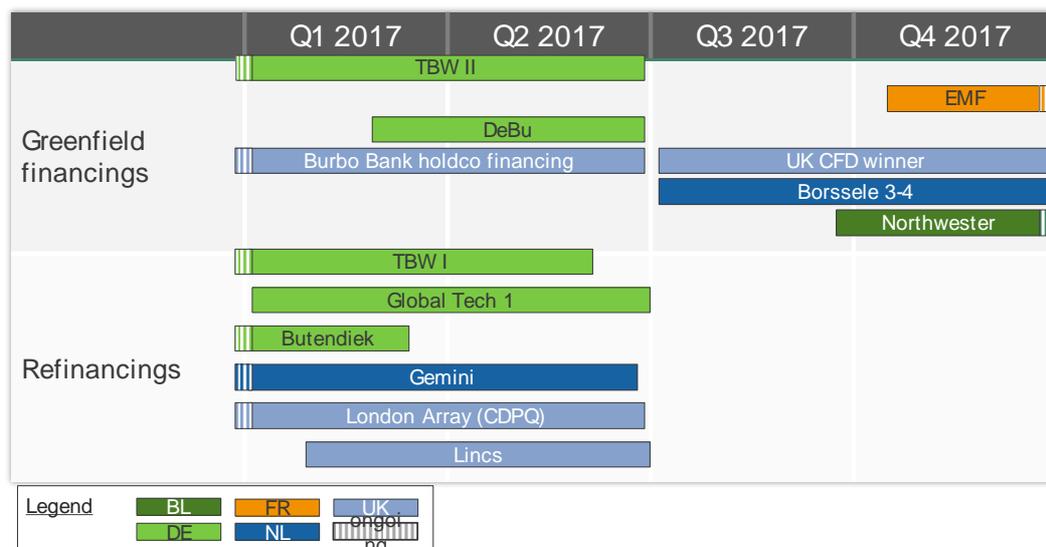
Investor and finance community

Prior to and during construction, utility-developers and/or IPP-developers account for most equity shareholding. Typically, utility-developers divest equity once a project is operational, however, this can vary depending on the risk appetite of the investor.

A majority of early offshore wind projects were funded on balance sheet, reflecting the preferences of early investors (i.e. utility-developers) rather than a lack of bank appetite. However, the proportion of project financed transactions has grown steadily since the first one in 2006 (the 120 MW Q7 project in the Netherlands) until 2011. These two routes (balance sheet or project finance) have been broadly equally used in recent projects.

Project finance funding of offshore wind projects can be considered as a mainstream option and indeed a substantial number of projects are expecting to use that route in 2017 (see Figure 31). The availability of project finance (and construction equity) has made it possible for relatively small players to successfully bring projects to financial close and to full operation on a regular basis.

Figure 31: Pipeline of project financed projects



Source: Green Giraffe, based on WindEurope data for new installations and internal database for project finance transactions

Supply Chain

With its infancies in Denmark, a number of WTG manufacturing facilities in the offshore wind industry are located in these areas, including Brande, Aarlborg, and the port of Esbjerg in Denmark. Since then, the industry has seen a growth and geographical diversification of the supply chain facilities, including the hubs in Rostock, Bremerhaven and Cuxhaven in Germany, as well as the Humber region in the UK where Siemens is establishing blade manufacturing facilities and DONG Energy is establishing a service harbour. Emerging markets in which no projects are yet operational aim to establish at least a partial domestic supply chain, including France, the USA and Chinese Taipei.

Balance of plant manufacturing facilities are more widely spread, including the UK, Germany, Netherlands, Belgium, France, Spain, and South Korea. The majority of the supply chain and value creation to date though remains in Europe.

However, a number of plans for manufacturing facilities across Europe have been cancelled or put on hold over the last years due to delays in projects and market growth, as well as a lack of confidence in the size of the market beyond 2020. Overall, as was confirmed by stakeholder interviews, the level of competition has improved and the overall supply chain is perceived to be more robust than a few years ago.

6.4 PROJECT RISK MANAGEMENT

Policy & regulation, as documented above, can have a major influence on the risk profile for wind farm developers. However, developers themselves can employ a range of tools and strategies to limit their risk exposure. Key findings include:

- Collaboration within the industry helps to manage developer risks on large-scale projects under auction regimes
- More successful projects build a strong management team and have fall-back plans in place
- Strong relationships with regulators, executing authorities and third parties lead to more successful projects
- Continued innovation is required to achieve cost reductions
- Developers do not require all risks to be mitigated, but regulatory frameworks need to ensure risk-reward balance for developers
- Allocation of grid connection risk to the grid operator by regulators requires effective performance incentives for the grid operator

Project lifecycle risks

Project risks are varied and are influenced by different drivers. The primary lifecycle risks can be classified as:

- **Allocation risk:** Risk of securing a site, the right to develop, construct and operate an offshore wind farm and/or to obtain revenue support
- **Price risk:** Competitive auctions, wholesale price volatility and commodity price volatility.
- **Development risks:** Risk of cancellation of the project during the development phase (potentially EUR 10s of millions) due to fatal flaws / non-feasibility due to environmental & permitting issues, undue ground risk, grid connection approval issues etc.
- **Funding risks:** Risk of not finding enough funders or delays in obtaining funders approval
- **Construction risks:** Risk of cost overrun or delays due to adverse weather, interface risks, bottlenecks in the supply chain, etc.
- **Operation risks:** Risk of cost overrun and/or underperformance due to accessibility risk, lead time for spares and logistics, bottlenecks in specialist maintenance staff

Developer risk mitigation tools

Where possible, developers aim to wholly eliminate or avoid risk at a development and design stage. Passing risks on the third parties, typically construction and operation contractors, is a key tool for developers to manage risks. To ensure affordability, the level of risks assumed by contractors is typically limited and/or shared with developers. Where residual risks cannot be fully foreseen or mitigated through design out, or passing on to third parties is not viable, contingency budgets and insurance may be required.

Table 28. Developer risk mitigation tools

Risk mitigation tool	Objective	Example	Cost impact on developers
Design out	Eliminate risks by development of safe designs or avoidance of risk through technology selection.	E.g. Revision of design standards for foundations to mitigate grouted connection failure in monopiles.	
Pass on to third parties	Pass risks on to parties that are best placed to control and manage the risk	E.g. Pass on P50 weather risk to construction contractors	
Contingency	Allow for a contingency budget for risks that cannot be mitigated with the above strategies	E.g. Include construction contingency for known and unknown risks, such as residual interface risk E.g. Include float for delays in schedule of works between the works of different construction contracts	
Insurance	Take out insurance for risks that cannot be mitigated with the above strategies	E.g. Insurance for public liability or unforeseen loss	

Developer risk mitigation strategies

Developer risk mitigation strategies are diverse and subject to regulatory framework design, site specific environmental, permitting and technical risks, the status of the wider industry, and competing technologies and markets. General mitigation strategies that should be applied include:

- Assurance that good industry practice is followed through deployment of experienced management teams and contractors
- Collaboration with other developers and supply chain, e.g. form consortia to spread allocation and development risks, secure funding, and drive innovation
- Collaboration with regulators and executing authorities to mitigate non-compliances
- Establish fall-back plans early in the development process and maintain flexibility in the approach to development, e.g. include float in schedule, reduce reliance on single points of failure, one-of-a-kind equipment
- Get project agreement and the project's execution strategy third party reviewed early in the process to check that risk mitigation is adequate

Trends in developer risk profiles

The introduction of auctions in Europe has on the one hand materially increased the developers' allocation risk and, on the other hand, where centralised site-specific auction models are applied, led to a reduction of the development risk. Funding, construction, and operation risks are decreasing primarily through industry learning, improving capabilities and competition in the market. However, it must be acknowledged that technologies are still evolving at a fast pace and the industry continues to transition to site in deeper more challenging waters which may face developers with new challenges.

Table 29. General trends in developer risk levels

Project risk category	Trends in developer's risk level	Drivers
Allocation risk		<ul style="list-style-type: none"> • Introduction of auctions and cap on market growth • Trend towards “central model” with site selection by regulator and cap on market growth rate • High levels of competition under auctions to date • Uncertainty over timing and size of auction rounds • Need for differentiated support for innovative technologies
Price Risk		<ul style="list-style-type: none"> • Competitive auctions create strike price uncertainty. • Wholesale price uncertainty. • Commodity price volatility.
Development risk		<ul style="list-style-type: none"> • Trend of regulators assuming part or majority of the development scope to derisk projects for developers, to increase chance of project realisation and to meet policy targets. • Increasing project size and scale of overall industry requires coordinated approach to grid connection.
Funding risk		<ul style="list-style-type: none"> • Increasing trust by funders • Attraction of new funders to the market • Increase in project size requires greater number of funders per project
Construction risk		<ul style="list-style-type: none"> • Learning of the industry • Greater trust in contractor capabilities • Greater availability and competition of contractors • Continued evolution of technologies and use of technologies with limited track record • Sites conditions become more challenging (deeper waters, further offshore, larger capacity and larger equipment) • Increasing cost reduction pressure due to lower tariff levels
Operation risk		<ul style="list-style-type: none"> • Learning of the industry • Greater trust in contractor capabilities • Greater availability and competition of contractors • Limited track record of aging assets • Sites conditions become more challenging (deeper waters, further offshore) • Increasing cost reduction pressure due to lower tariff levels
		 Decreasing  No clear trend/mixed drivers  Increasing

6.5 RECOMMENDATIONS FOR POLICY MAKERS

Analysis of the evolution of offshore wind policies has revealed several important lessons with regard to best practice approaches for stimulating deployment and reducing costs.

Governments should re-evaluate their offshore wind ambitions in light of accelerated cost reduction

Offshore wind is entering a maturation phase which has already seen costs fall dramatically in early tender rounds. With further cost reduction anticipated, offshore wind could potentially be fully integrated into the market on a competitive basis in some European countries within the next decade⁶⁵. In light of this development, governments should re-evaluate their energy strategies to consider raising ambitions for future deployment.

Governments should consider implementing near-term roadmaps to hedge against long-term uncertainty

Long-term visibility is a common request from industry players, but does not always align with short term political cycles. As a compromise, near-term roadmaps – tied to suitable support mechanisms – can provide the necessary certainty and stability to increase market confidence. This approach has been particularly effective in the Netherlands, with Germany set to adopt a similar approach.

Competitive auctions can drive down costs, but should be accompanied by government de-risking activities

The transition to competitive auctions has been hugely effective in delivering steep cost reduction. However, in order to deliver future cost reduction governments are likely to need to mitigate increased allocation and price risk by undertaking site development activities to de-risk investments from developers. Undertaking spatial planning and constraint mapping to identify sites, making site survey data publically available, and securing necessary permits can all significantly limit the risk exposure for developers. In countries with established industries, enabling the extension of existing sites can also unlock lower risk and lower cost means of adding new capacity.

Policymakers in more isolated emerging markets are still likely to require attractive support mechanisms and enabling policies to kick-start domestic industries

The progress and cost reduction achieved in Europe has been partly attributed to clustering and concentrated development around the North Sea region. For more isolated emerging markets, such as Japan, Taiwan, and the United States, greater public intervention is expected to be necessary to de-risk investment and develop the necessary industry structures to deliver cost-effective offshore wind projects.

Governments must continue supporting technology innovation to achieve long-term cost reduction

The cost reduction achieved in recent years has been largely driven by technology innovation. Despite the considerable progress made to date, policymakers should not step back from efforts to support research and development activities. Rather, government R&D support should be expanded to develop and de-risk technologies that will be crucial to achieving long-term cost reduction. This is particularly relevant in relation to developing larger turbines and associated supporting infrastructure, commercialising floating wind technology to unlock new markets for offshore wind, and developing technologies to withstand extreme weather conditions in these new markets.

Regulatory frameworks should encourage industry collaboration and information sharing

Despite the transition to more competitive market conditions, continued industry collaboration will be vital to accelerating learning and maximising the impact of both public and private investment. Governments should look to foster collaborative partnerships, forums, and programmes to overcome common challenges, particularly as the industry expands to new markets.

⁶⁵ The Dutch Government have outlined plans to hold the first tenders for un-subsidised offshore wind farms by 2026.

6.6 RECOMMENDATIONS FOR INDUSTRY PLAYERS

The offshore wind industry has evolved considerably in recent years: the supply chain has developed, developers have become better at managing risk, and the investment community has greater confidence in the industry as a whole. The following recommendations are derived from the lessons learned and should be applied by industry players in established and emerging markets.

Embrace collaboration within the industry to manage developer risks on large-scale projects under auction regimes

The introduction of auction regimes in Europe has introduced greater allocation risk for developers. Furthermore, project capacities are growing and with it the capital required and impact of failure of a single project on a developer's overall business. Developers have approached these trends through collaboration and forming of consortia between developers and/or with stakeholders from the supply chain to share risks and increase the chance of winning bids, as well as maintain a reasonably-sized project pipeline.

Build a strong management team and have fall-back plans in place

Developers' risks are now well understood and effective risk mitigation strategies have been identified. To ensure industry lessons learned are applied and learning is continued, an experienced project management team is pivotal to the success of a project, as well as robust planning and fall-back plans. Developers should involve independent advisors early in the planning phase when optimisation of the procurement and execution strategy is feasible and has the potential for large savings later on in the project.

Build strong relationships with regulators, executing authorities, and third parties

In particular, in emerging markets with little or no experience on the regulator side, industry should engage early with regulators, interfacing authorities and third parties to clarify requirements and establish a collaborative and constructive dialogue. Industry players should participate in stakeholder consultations held by regulators to mitigate unrealistic requirements or unintended risks being introduced to developers and their funders.

Continue to innovate

European offshore wind tenders awarded in 2016 confirm that developers need to achieve material cost reductions to what has been seen in the industry to date. Developers cannot solely rely on established technologies, but need to seek to continue to innovate. This can be achieved through participation in industry R&D initiatives, collaboration with universities and supply chain or regulator-supported pilot-schemes. Developers should engage early with potential funders to familiarise them with potential innovations and risks mitigation strategies.

Engage more with the public to improve the public perception of the offshore wind industry

The public perceives offshore wind to be less reliable and more expensive than other forms of electricity generation. More could be done by the industry to improve its public standing by promoting the importance of offshore wind in maintaining grid stability, the recent gains in cost reductions, and the benefits to local and regional economies.

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APPENDIX

METHODOLOGY

Overview

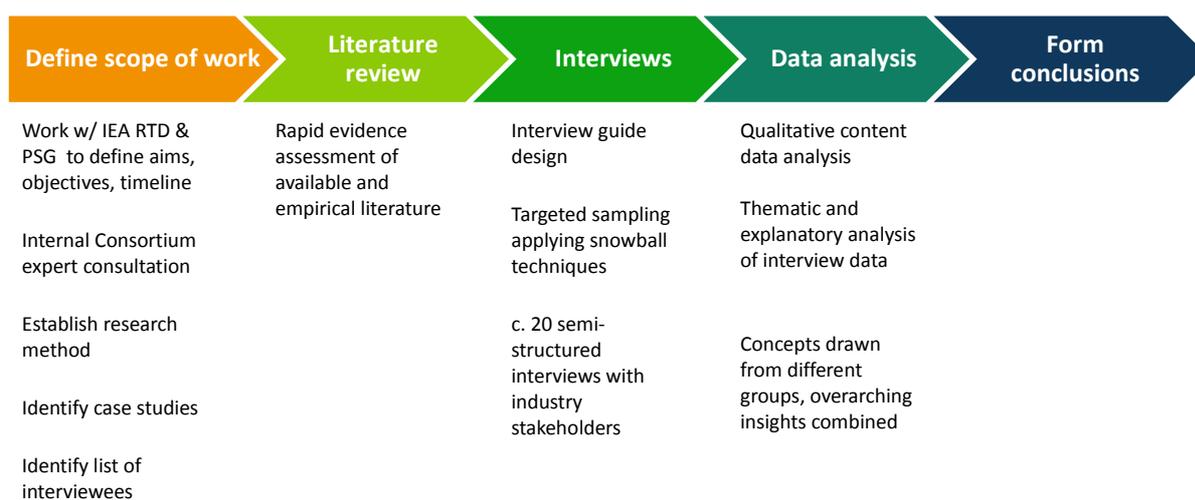
The report has been produced as part of a collaborative partnership between the Carbon Trust, Mott MacDonald, and Green Giraffe, all of whom have leaned on considerable industry expertise from having been at the forefront of the offshore wind industry over the past decade. Insights have been drawn from a combination of in-house knowledge and experience, an extensive literature review, and a series of targeted interview with key industry stakeholders.

Approach

The study leant on primary and secondary data in order to answer the proposed research questions. Market intelligence was gathered through a combination of literature reviews and a series of targeted interviews. Together these sources provided a comprehensive narrative and picture on how offshore wind has developed across leading front runner markets with the aim to help inform emerging market policy design. Both secondary and primary data were the predominant sources used to answer the research questions, with key insights drawn out through interviews with stakeholders. Existing literature on leading and emerging markets, and associated suite of offshore wind policies and market structures, is deemed to be of good quality. This secondary data was therefore be used to build a strong evidence base for the analysis, and inform the design of interview guides. Interviews with key industry stakeholders were used to draw out opinions and nuances on pertinent aspects such as policy effectiveness, impact on project risk profile, and perceived best practice.

A multi-step, iterative process was pursued, as illustrated in Figure 32. The proposed method was aligned with qualitative research concepts, methods and theory outlined within Bryman, A. (2015) *Social Research Methods* to ensure validation.

Figure 32. Methodology overview



At the outset of the study, we consulted with the IEA-RET D PSG and internally across the implementing bodies’ in-house experts to refine the scope of work and research method.

Case studies

Across the publication we developed a number of case studies. These were identified from the outset as being integral to the development of insights and recommendations within this report. By focusing on a particular subset of countries and specific generation projects we were able to draw out important insights for those markets seeking to introduce and scale up offshore wind deployment today, and for those looking to integrate offshore wind assets in the short to medium term.

Case studies were identified at country and project level, in addition to further case studies on industry structures.

Secondary data collection

A rapid evidence assessment⁶⁶ of existing literature and market data was undertaken. Full details of the literature reviewed can be found in the ‘References’ section.

Primary data collection: Interview sampling approach and data collection

Following selection of the case study countries and projects, a list of potential interviewees were identified, in order to provide added insights for the project. A total of 25 interviews were conducted with a range of stakeholders including developers, investors, OEMs, regulators, transmission operators, and academics.

The interviews provided valuable insights to inform each of the three main sections and report objectives. The interviews sought to complement the literature review by:

- Validating findings from the literature review
- Drawing out insights and opinions on what policies have been effective, and conversely which haven’t been conducive to industry growth
- Outlining the key challenges from the perspective of government bodies, developers, and the supply chain

The interviews were conducted through semi-structured telephone interviews (or in person depending on circumstance). Semi-structured interviews allow for probing and follow-up questions, and encourages the emergence of unforeseen concepts and insights. Where appropriate, follow-up communication was undertaken confirm and validate information.

The data collection period ran from week 6 to week 10 of the project. In order to ensure that the interviews were designed appropriately and fit-for-purpose we conducted a small number of pilot interviews at the beginning of the process. This allowed an opportunity to verify the current approach and make any necessary adjustments to the interview structure and format. Furthermore, the staggered inflow of data over the interview period provided the opportunity to iteratively explore the data and reformulate questions based on early responses.

Data Analysis

Following the data collection period, we applied standard interview response analysis techniques and applied thematic and explanatory analysis to the interview data sets to draw out key themes.

⁶⁶ Rapid evidence assessments provide a structured, stream-lined, and rigorous search of available literature and result in a quality and synthesised assessment of the evidence. They are less extensive than a comprehensive or systematic literature review, which can take months to deliver. Importantly, the REA method aligns with the requirements, time and resource available within this study.

Limitations to the study

Given the high number of case studies across different jurisdictions in tandem with limited time and resource we recognise that seeking thematic saturation will be difficult. Theoretical saturation or thematic exhaustion is the point at which each additional data response does not introduce new narratives or pertinently impact the data trend. Due in part to diverse groups and low sample sizes in each group, the interview findings are unlikely to achieve thematic exhaustion. As we identified this in advance we conducted the interviews with the aim of complementing and challenging the findings of the secondary data collection.

In addition, because we applied a purposeful and targeted sampling approach (i.e. not random), it may not be possible to generalise the findings to the entire population. Sampling bias is therefore a potential risk and should be acknowledged. However, given the diligence applied within the approach to scope in key players within the interviews, we consider the entailed generalisation to be valid.

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IEA RETD TCP aims to empower policy makers and energy market actors to make informed decisions by: (1) providing innovative policy options; (2) disseminating best practices related to policy measures and market instruments to increase deployment of renewable energy, and (3) increasing awareness of the short-, medium- and long-term impacts of renewable energy action and inaction.

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