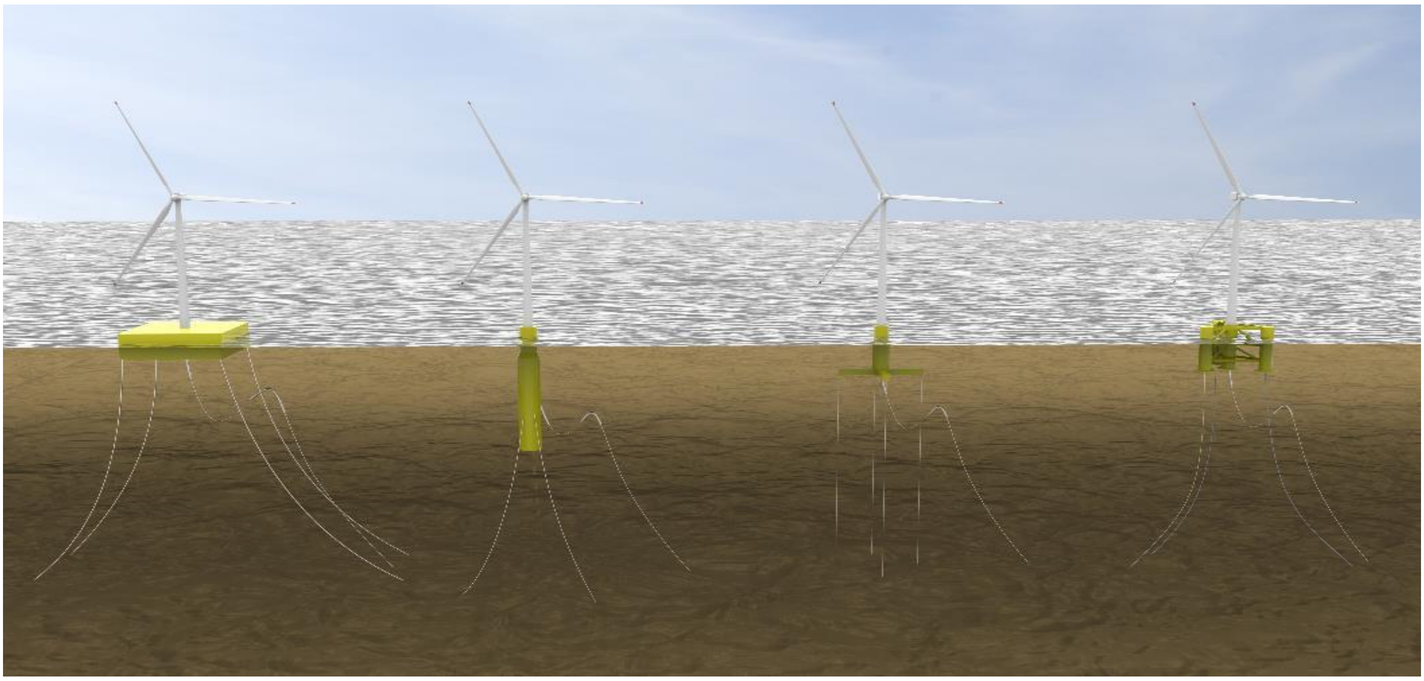
MACROECONOMIC BENEFITS OF FLOATING OFFSHORE WIND IN THE UK



DATE // September 2018

Contents

Glossary

Anchor Handling Tug Supply (AHTS) or Anchor Handling Vessels (AHV): mainly built to handle anchors for oil rigs, tow them to location, anchor them up and, in a few cases, serve as an Emergency Response and Rescue Vessel (ERRV).

Autonomous Underwater Vehicle (AUV): unmanned underwater vehicle which conducts its survey mission without operator intervention. It returns to a pre-programmed location when its mission is complete where the data can be downloaded and processed.

Contract for Difference (CFD): a private law contract between a low carbon electricity generator and the Low Carbon Contracts Company (LCCC), a government-owned company. A generator party to a CFD is paid the difference between the 'strike price' – the agreed price for electricity – and the 'reference price'– a measure of the average market price for electricity in the GB market.

Crew Transfer Vessels (CTV): used to transport wind farm technicians and other personnel out to sites on a daily basis.

Final Investment Decision (FID): the final decision of the Capital Investment Decision (CID) as part of the long term corporate finance decisions based on key criteria to manage company's assets and capital structure. In general, the FID can be made after completion of permits and financial arrangement, and ready for contract of the Construction works at the Site (EPC Contract).

Gross value added (GVA): the measure of the value of goods and services produced in an area, industry or sector of an economy

Heavy Lift Vessels (HLV): designed to move very large loads that cannot be handled by normal ships. They are of two types: Semi-submersible and Project cargo.

Levelised cost of energy (LCOE): the net present value of the unit-cost of energy produced over the lifetime of a generating asset

Original Equipment Manufacturer (OEM): a company that produces parts and equipment that may be marketed by another manufacturer (eg. turbine manufacturers are frequently referred to as OEM's)

Remotely Operated Underwater Vehicle (ROV): tethered underwater mobile device, unoccupied, highly manoeuvrable, connected to a ship by a series of cables.

Renewables Obligation Certificates (ROCs): the green certificate issued for eligible renewable electricity generated within the United Kingdom and supplied to customers in the United Kingdom by a licensed supplier. The Renewables Obligation (RO) closed to all new generating capacity on 31 March 2017. There have been early closures under the RO for solar photovoltaic (PV) and onshore wind.

Service Operation Vessel (SOV): a purpose-built vessel for the deployment and retention of offshore support and maintenance engineers.

Tension-leg platform (TLP)/extended tension leg platform (ETLP): vertically moored floating structure normally used for the offshore production of oil or gas and is particularly suited for water depths greater than 300 metres and less than 1,500 metres.

1 Executive Summary

Floating wind has made significant advances in recent years and is set to become a major contributor to global offshore wind capacity over the coming decades. Today, the UK leads the world in deployment of floating wind and has the opportunity to develop a sustainable industry supporting large-scale employment, exports and GVA.

Floating wind is an important counterpart to fixed offshore wind and will make an increasingly important contribution to realising the full potential of the sector.

Longer term, floating wind can contribute at least 10GW towards the UK achieving 50GW of offshore wind capacity by 2050 and large-scale deployment of floating wind will be imperative if the UK is to realise ambitions in excess of 50GW. Floating wind will support the UK offshore wind supply chain, with 57% UK content expected by 2031 and 65% by 2050. It will both provide jobs and retain skills for a declining yet important UK oil and gas sector.

With the UK's strong track record in fixed wind and world-leading subsea and offshore engineering capabilities, the UK is well placed to take advantage of the economic growth which can be achieved through developing this sector. We project that floating wind will support 17,000 UK jobs and £33.6bn of GVA, far outweighing the cost of providing support for the early stages of deployment of up to £2.2bn and representing a return of £15 for each £1 invested in early stage support.

The global opportunity for floating wind is large, with emerging markets in Japan, USA, China, Taiwan, Korea, Norway, Spain and Portugal. These countries represent both growing export opportunities but also competition for UK companies. The total market is set to grow to at least 4GW installed by 2030 and 55GW by 2050, representing annual markets of at least £3.1bn and £7.1bn respectively. Off the back of this, with the appropriate supportive actions, we believe the UK can deliver annual UK export value of at least £230m by 2031 and £550m by 2050.

In addition to these economic benefits, floating wind can enhance security of supply through addressing sites with consistent, high-speed wind resource in deep-water sites outwith the southern North Sea and Irish Sea, in particular off Scotland and the South-West of England, areas less likely to feel the economic benefits from deployment of fixed offshore wind.

The UK now has a short window of opportunity to capitalise on its early advantage and realise the long-term benefits. First and foremost, policy support is essential to provide private sector confidence to invest. This should include ring-fenced funding for floating wind in future Contracts for Difference auctions to support at least 100MW of pre-commercial projects by 2025, at a cost of £668m, and subsequent 800MW of first commercial-scale projects by at least 2027, at a cost of £1.2bn.

Infrastructure investment is also required to the tune of £800m, including port and fabrication facilities. There is clear appetite within the UK for private sector investment, but it does require public co-investment, estimated in the region of £350m.

In the past 3-4 years, floating wind has matured into a viable and proven technology. Our analysis predicts that, with conservative assumptions for UK and global deployment, floating wind can be cost competitive with fixed offshore wind by 2031.

The UK has early-mover advantage, with the recent successful commissioning of the world-first Hywind Scotland Project off Peterhead and there is a clear market evolving for the technology, which the UK is best placed to capitalise upon. The potential prize is significant and worth pursuing, but near-term action is required to realise it for the UK.

A key part of this study has been working closely with the steering group consisting of Crown Estate Scotland, The Crown Estate, Renewable UK and Scottish Renewables. Direct input of data and information along with feedback on draft findings has been received from key industry stakeholders. We thank all involved for their contributions.

2 Introduction

2.1 Aims of the Report

Offshore wind is rapidly becoming the lowest-cost form of large-scale electricity generation. The UK is currently at the forefront of the global offshore wind market and has the opportunity to remain there. The UK's Clean Growth Strategy clearly recognises that the cost of supporting new low carbon technologies can be viewed as an investment, provided there is long-term cost reduction, economic value and jobs supported, and reduced carbon emissions. Making the case for supporting any new generation technology must therefore focus on these aspects.

It is in this context that this report has been commissioned by Crown Estate Scotland to set out the potential macroeconomic consequences arising from public policy support for the early stages of UK floating wind deployment.

The following sections of this report document the modelling assumptions and conduct scenario analysis to set out the expected costs and economic benefits associated with different forms of policy support for the early stages of UK floating wind deployment. The aim is to demonstrate how costs incurred today in supporting floating wind will create sustainable value to the UK over the long term.

2.2 Global Floating Wind Opportunity

2.2.1 Floating Wind Market Potential

Floating wind is the use of floating substructures anchored to the seabed, supporting turbines in areas where waters are too deep, and/or the seabed is unsuitable for bottom-fixed foundations to be economically viable. Floating solutions can be used in far-shore deep-water locations to harness stronger wind resource than is available closer to shore, or in nearer-shore locations with deep water. The global potential market for floating wind is significantly larger than that for bottom-fixed offshore wind due to the extent of deep waters which are suitable for floating wind but commercially unviable for bottom-fixed foundation technology. In general, areas suitable for floating offshore wind are expected to have better wind conditions. It has been estimated that 80% of the potential offshore wind resource in Europe (4,000GW) and Japan (500GW) and 60% of potential offshore wind resource in the USA (2,450GW) is in waters of 60 metres or deeper[1].

The UK is currently a world-leader in floating wind with the world's first floating wind demonstration array, the 30MW Hywind Scotland project, being commissioned in 2017 and having achieved an average capacity factor over November 2017 – January 2018 of 65%.

Other key emerging global markets include Korea, Japan, Taiwan, USA, France and Spain (particularly the Canary Islands). A combination of renewable energy commitments, a lack of sufficient shallow water

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[1] www.thecrownestate.co.uk/media/5537/km-in-gt-tech-122012-uk-market-potential-and-technology-assessment-for-floating-wind-power.pdf
www.mofa.gov.tw/Upload/RelFile/2508/111034/25bcd458-67d7-4ed4-994b-128a7ba49d17.pdf

sites in locations with strong wind resource and the absence of an established bottom-fixed offshore wind market make these countries natural early adopters of floating wind.

With this level of global potential, floating wind will play a key role in the future of offshore wind and global momentum is growing. In Europe, France has awarded 96MW of floating wind capacity due to be operational by 2020, Portugal has the existing Windfloat project with further capacity due to be operational in the early 2020's and the Flocan and Nautilus projects to be commissioned by 2020 in the Canary Islands. In Asia, Japan's demonstration sites include the Fukushima project and, in China, the Fujian Xiapu Eagle Island Floating Project is due to be operational by 2020. In the USA, the offshore wind industry is gaining momentum, and there is a clear logic for deploying floating wind off the coasts of California and Hawaii.

These countries represent key potential export markets for the UK provided momentum in the UK is continued with further floating wind projects, allowing the UK to remain at the forefront of global floating wind.

2.2.2 Floating Wind Industrial Potential

In addition to unlocking large amounts of high quality offshore wind resource, floating wind presents a significant industrial opportunity. The fabrication and assembly of large, heavy steel and concrete structures, plus their installation and maintenance, fits well with industrial capabilities in countries, including the UK, with established expertise in construction, oil & gas, and shipbuilding. There is also a large opportunity for the export of services and skills for countries like the UK with a long track record in related industries. Norway, for example, has recently announced that Equinor will build an 88MW floating wind project to provide power to the Gullfaks and Snorre oil fields and is planning to proceed with one or more floating wind demonstration projects in order to demonstrate the Norwegian industry's capability in this sector.

There is increasing focus in the UK and a number of other countries on the amount of value from renewable energy projects which can be retained domestically (local content) and the value which can be achieved from exporting technologies. This puts an emphasis on pursuing technologies suited to the local environment, developing strength in elements of the value chain with the highest value and export potential and building on existing strengths.

Different countries will be able to benefit from floating wind in different ways and over different time horizons. For example:

> **Japan** has invested heavily in technology development and demonstration, and has an abundance of potential deep-water sites. It can benefit from floating wind deployment through clean energy generation, but has no offshore wind or strong offshore oil & gas heritage, making it a likely importer of technology and solutions in the short-term at least.
>
> **South Korea**, on the other hand, has great floating wind potential plus an internationally highly competitive shipbuilding industry with the port facilities and fabrication yards necessary to

successfully deploy and export floating wind turbines, making the country a logical first mover (and logical exporter to Japan).

The UK already has a well-established and relatively mature offshore wind market, including a known pipeline of projects in the short to medium term. The clean energy imperative from floating wind is not immediate. However, the UK offshore wind supply chain continues to grow, gaining ever larger shares of the domestic and export markets. The UK is also home to many world-leading oil & gas companies who routinely provide goods and services around the world. Floating wind therefore presents an industrial opportunity even in the short-term, with some level of domestic market and a growing export market, as well as unlocking the full extent of UK offshore wind resource potential.

2.2.3 Floating Wind Status

A number of floating concepts are on the verge of commercialisation and are seeking a route to market, but the floating wind industry is still in the early stages compared to bottom-fixed offshore wind. The small scale of test and demonstration projects means that floating wind costs achieved to date have been much higher than for fully commercial bottom-fixed projects. Significant cost reductions will be achieved with commercial-scale projects, through economies of scale, reducing cost of capital and ongoing supply chain innovations.

There are currently a number of technology and commercial challenges and various initiatives are underway to address these. Technical challenges include turbine control, electrical connections and dynamic cables, optimised installation and operations and maintenance (O&M) processes and large seabed footprint for some floating substructures. Key commercial challenges relate to securing route to market and agreeing contract warranty terms with turbine OEM's. Work is already underway to address these issues through joint industry initiatives led by the Carbon Trust[2] and projects by the ORE Catapult[3].

The combination of large-scale clean energy, industrial benefits and cost reduction potential means there is a strong case for supporting floating wind deployment and for developing the relevant supply chain capabilities to capitalise on the opportunity. However, the rapid cost reductions in bottom-fixed offshore wind implied by recent auction results means that it is difficult for policy makers in countries with mature offshore wind markets to demonstrate value for money in supporting generation technologies which are not currently cost-competitive.

2.3 UK Floating Wind Opportunity

2.3.1 UK Industrial Strategy and Clean Growth Strategy

In 2017, the UK government published its white paper on industrial strategy, which sets out a long-term plan to boost the productivity and earning power of people throughout the UK. This puts a significant

[2] https://www.carbontrust.com/media/675868/flw-jip-summaryreport-phase1.pdf
[3] https://ore.catapult.org.uk/app/uploads/2017/12/An-Introduction-to-Risk-in-Floating-Wind-_-Roberts-Proskovics-_-AP-0014.pdf

focus on industries where the UK can build world-leading export capabilities. As detailed in the supply chain analysis in Appendix 4, UK companies are well positioned across the floating wind value chain.

A key element of the Industrial Strategy is the Clean Growth Strategy, published in 2018, which sets out how the UK can "maximise the advantages for UK industry from the global shift to clean growth – through leading the world in the development, manufacture and use of low carbon technologies, systems and services that cost less than high carbon alternatives."[4]

The Clean Growth Strategy recognises that the UK has world-leading capabilities and significant opportunities in various areas of energy systems, including offshore wind, and provides commitment to supporting innovation so that costs of clean technologies, systems and services are reduced across all sectors. The Strategy also highlights that the progress made in technology and cost reduction in a number of forms of clean generation "has altered the way that we see many of the trade-offs between investing in low carbon technologies that help secure our future but that might incur costs today. It is clear that actions to cut our emissions can be a win-win: cutting consumer bills, driving economic growth, creating high value jobs and helping to improve our quality of life."[5]

This philosophy of developing solutions today to save money and increase energy security in the longer term has been given even further strength by the Committee on Climate Change (CCC) 2018 Progress Report to Parliament[6], which concluded that the UK is not on course to meet its legally-binding emissions reduction targets in the fourth and fifth carbon budgets (2023 – 2027 and 2028 – 2032). One of the key priorities identified for development of government policy include "Government should actively investigate the cost reduction potential of emerging low-carbon technologies with a large potential scale of deployment in the UK, and, where appropriate, provide R&D and demonstration and deployment support. Floating wind turbines is an example of one such technology."

2.3.1 Offshore Wind Sector Deal

Under the Industrial Strategy umbrella, the UK Offshore Wind Industry Council (OWIC) is seeking to establish a sector deal with the government, which will build a partnership to address industry issues and deliver economic and industrial benefit to the UK. Key themes of the proposed sector deal are cutting-edge innovation, development of a globally-leading supply chain, affordable clean growth, creating a highly-skilled workforce and transforming coastal communities. The proposed deal includes target UK offshore wind capacity of 30GW by 2030 and 50GW by 2050. We understand that the upper end of industry ambition for 2050 is 70GW, which can be achieved with the appropriate support for generation and transmission solutions to access a greater portion of UK offshore wind resource. Floating wind is

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[4] UK Clean Growth Strategy:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/664563/industrial-strategy-white-paper-web-ready-version.pdf
[5] UK Clean Growth Strategy Summary:
https://www.gov.uk/government/publications/clean-growth-strategy/clean-growth-strategy-executive-summary#fn:26
[6] https://www.theccc.org.uk/wp-content/uploads/2018/06/CCC-2018-Progress-Report-to-Parliament.pdf

specifically included as part of the sector deal innovation workstream and is relevant to all of these elements.

A number of factors make floating wind attractive to the UK from an Industrial Strategy and sector deal perspective:

- The global market potential for floating wind is even larger than for bottom-fixed offshore wind, representing a vast export market, creating UK economic value and jobs;
- The UK is currently the global leader in floating wind and bottom-fixed offshore wind deployment, putting the UK in prime position to exploit the export opportunity by leveraging on experience;
- The UK has a long-established oil & gas supply chain, with a large amount of skills transferable to floating wind;
- As with oil & gas and offshore wind to date, core skills in development, design, engineering and maintenance are highly exportable;
- Achieving 50GW of UK offshore wind can be enabled with the inclusion of floating wind and the upper end of industry ambition of 70GW, which is important to maximising UK offshore wind output for meeting emissions targets and to attracting key elements of the supply chain to locate to the UK, will require significant floating wind deployment;
- The cost reduction potential of offshore wind is already being demonstrated with ever-reducing auction prices and floating wind, being a subset of offshore wind, can prove the same with volume deployment and further supply chain development; and
- There are a number of UK coastal communities which have not yet had the opportunity to benefit from offshore wind due to the lack of suitable shallow-water or suitable seabed sites, where floating wind can support local investment and jobs.

2.4 Geographic Diversification

2.4.1 Security of Supply

Floating wind has the potential to provide increased stability and security of energy supply by locating projects in areas that currently have with very little or no economically accessible bottom-fixed offshore wind capacity. Floating wind allows further economic expansion and geographic diversity in the offshore wind portfolio to encompass much greater areas off the coast of Scotland, the South West of England, Wales and Northern Ireland. This could decrease the risk of UK offshore wind energy being over-exposed to the wind regime of the southern North Sea and Irish Sea. It also provides a natural element of balance, with more points of entry onto the grid, including close to demand centres in the South West of England, rather than multi-gigawatts connecting to the transmission network in few locations clustered close together.

2.4.2 Economic Reach

Enabling offshore in new locations also means that several coastal areas, which do not have sites nearby suitable for bottom-fixed projects, can benefit from the economic regeneration which has accompanied offshore wind activity in areas such as the Humber, East Anglia, Barrow and Belfast. Figure 1 shows an illustrative picture of the current portfolio of operating and development offshore wind projects (with recently awarded projects highlighted), compared to significant locations in the North East, North West and South West of the UK well suited for floating wind (with Hywind Scotland and Kincardine projects highlighted).

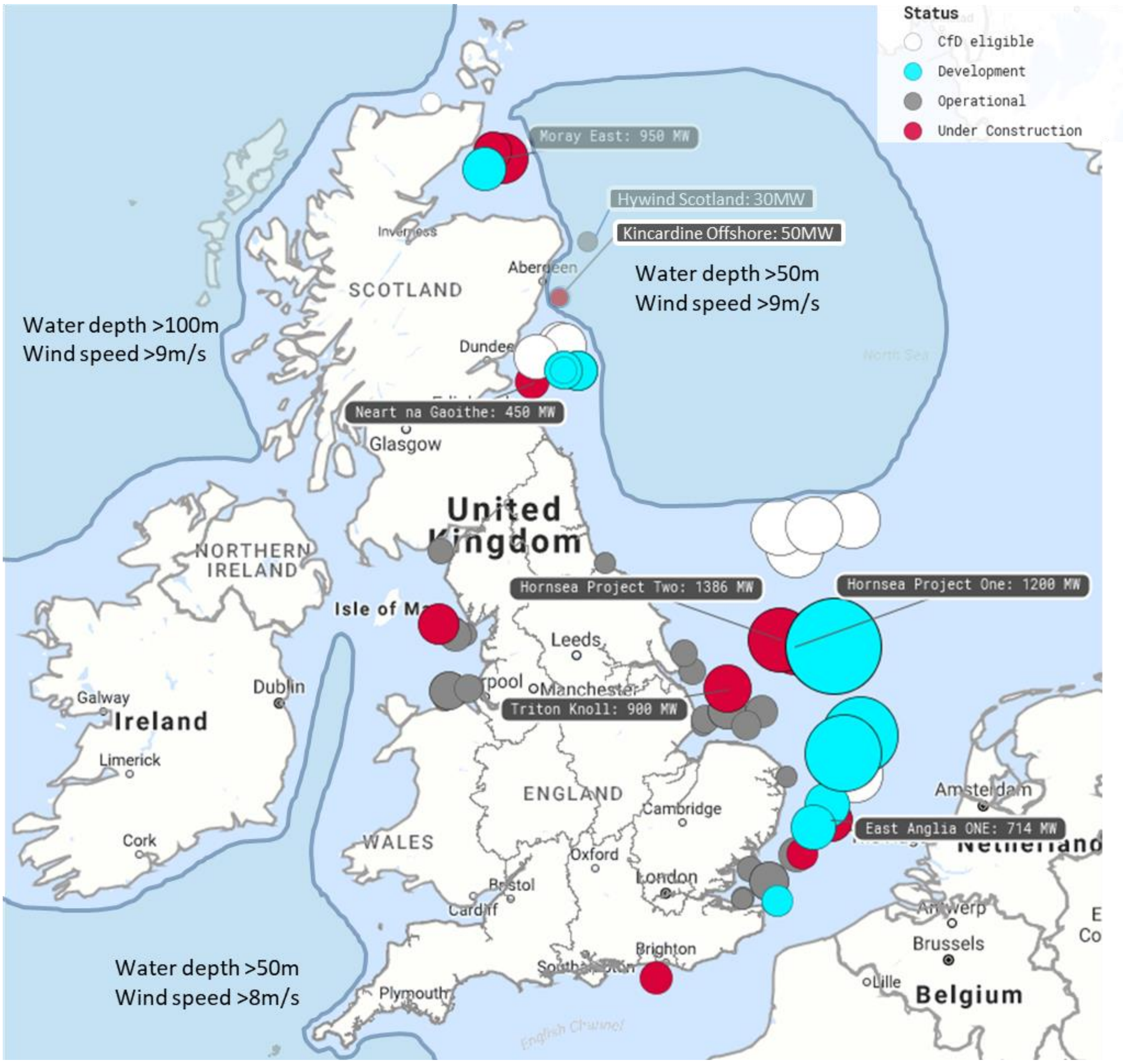

Figure 1: Indicative floating wind locations compared to existing UK offshore portfolio (Sources: DNV-GL, 2014 via Carbon Trust, Floating Offshore Wind: Market and Technology Review 2015; and ORE Catapult mapping via Espatial.com)

3 Methodology

In order to conduct this study, ORE Catapult has conducted economic modelling, policy analysis, scenario and sensitivity analysis. The inputs have been formulated and checked using a combination of direct stakeholder engagement, previous project experience and secondary research.

3.1 Economic Modelling

The macroeconomic benefits and costs of supporting the early stages of UK floating wind deployment have been modelled using an ORE Catapult in-house Excel-based economic model.

Macroeconomic benefits are assessed in terms of amount of Gross Value Add (GVA) and number of jobs supported. GVA measures the total economic income produced in an economy in a period of time and is a widely accepted metric for measuring economic value. GVA provides a monetary value for the amount of goods and services that have been produced, less the cost of all inputs and raw materials that are directly attributable to that production. It is also referred to as the sum of capital and labour income.

To estimate the macroeconomic benefits of floating wind, the supply chain has been split into a number of cost centres, each of which has been mapped to established industry sectors. For each of these industry sectors, published Input-Output tables, GVA multipliers, average salaries and employment multipliers are available. These are used to calculate GVA (direct, indirect and induced) and jobs (direct and indirect) supported based on the forecast expenditure in each cost centre.

A full description of the GVA and jobs estimation methodology is provided in Appendix 1.

3.2 Key Assumptions

The economic modelling is underpinned by a number of key assumptions, which are documented in the following sections.

3.2.1 Floating Wind Costs Over Time (see Section 4)

Current and future costs, expressed as Levelised Cost of Energy (LCOE), determine the extent to which floating wind projects require revenue or other financial support to be economically viable. The cost estimates described in Section 4 of this report have been formulated based on industry input solicited specifically for this study, supplemented with ORE Catapult experience.

3.2.2 UK and Global Deployment Rates (see Section 4)

The rate of capacity deployment, expressed as gigawatts (GW) and megawatts (MW), together with the costs of deployment, determines the size of the addressable market and the amount of revenue support required. Assumptions for UK and global deployment have been formulated within the context of wider offshore wind deployment and the anticipated timing of floating wind adoption in relevant markets, including the UK.

3.2.3 UK Supply Chain Share of the UK and Global Floating Wind Markets (see Section 5)

The share of the market captured by UK companies, referred to as UK content %, determines the domestic market value retained in the UK and the value achieve by UK companies exporting to overseas projects. Assumptions for UK content under 3 separate scenarios have been formulated based on direct industry input and with reference to current and expected levels of UK content in bottom-fixed offshore wind projects. This section also includes specific supply chain case studies to demonstrate capabilities.

3.3 Policy Analysis (see Section 6)

In order to assess the potential macro-economic consequences arising from public policy support for the early stages of UK floating wind deployment, three forms of policy support have been analysed:

- Revenue support for early commercial-scale projects
- Support for pre-commercial projects; and
- Co-investment in key supply chain elements

Each of these will have a different impact on expected levels of UK content in the maturing floating wind market (in both domestic and export markets) and has implications for the cost of early stage support.

3.4 Scenario and Sensitivity Analysis (see Section 7)

A range of potential costs and benefits associated with public policy support for the early stages of UK floating wind deployment are assessed through scenario analysis based on combinations of the above three forms of policy support. Scenarios are compared to highlight the cost and benefit implications of adopting different policy approaches.

Sensitivity analysis has been conducted on the scenario modelling results in order to assess the impact of changes to key assumptions and identify any key risks and potential upside associated with the different policy options.

3.5 Stakeholder Engagement (See Appendix 2)

A key part of this study has been direct input of data and information and feedback on draft findings from key industry stakeholders. Input was received through a combination of online surveys, telephone interviews and face-to-face meetings. Critical feedback on draft findings and input into UK content levels and policy support requirements was received during an industry workshop, attended by twenty industry participants plus attendees from The Crown Estate Scotland, The Crown Estate, Scottish Renewables and ORE Catapult. The list of engaged industry parties is shown in Appendix 2.

Industry input has fed into each stage of the methodology detailed in the following sections.

3.6 Technology Neutrality

This report aims to be technology-neutral and so estimates of cost and value represent a generic view, rather than being specific to any one floating wind typology. However, where relevant, the analysis does highlight differences between typologies in the challenges faced, potential solutions and where the UK supply chain may be better placed to capitalise in the domestic and export markets.

An overview of the key features of the types of floating wind substructures considered in this report (Barge, Semisubmersible, Spar and Tension Leg Platform (TLP)) is provided in Appendix 3.

4 Floating Wind Cost and Deployment Assumptions

This section documents and provides background to the assumptions used in this study for how the global floating wind industry will develop independently of the UK choosing to support the early stages of UK floating wind deployment.

4.1 Global Floating Wind Costs

4.1.1 Cost Estimate Sources

Key modelling inputs for cost estimation have been obtained by benchmarking ORE Catapult internal analysis, based on work carried out for various projects, against external input from selected technology developers. This external input has been selected based on technology developers who are currently in the process of developing or deploying pre-commercial arrays and who have engaged in detail with supply chain companies. Costs have been estimated for projects at a range of industry maturity: Demonstration Arrays, Pre-commercial Projects (a potential stepping stone between demonstration and commercial-scale projects) and First Commercial Windfarms.

The key inputs and resulting LCOE's are summarised in Table 1. The cost reduction drivers are explained in the following narrative.

Parameter (All costs shown in 2017 terms)	Unit	Demonstration	Pre-Commercial	First Commercial
Approx. Year	**Year**	**2018**	**2025**	**2027**
Turbine Numbers	#	5	12	50
Turbine Rating	MW	6	8	10
Site Capacity	MW	30	96	500
Project Life	Years	20	25	25
Net Capacity Factor	%	50.0%	50.0%	52.5%
WACC (pre-tax real)	%	10.0%	8.0%	7.0%
Devex	£/kW	200	170	150
Capex	£/kW	6,350	5,075	3,270
Opex	£/kW	120	115	110
Decommissioning	£/kW	1,200	365	165
LCOE (2012 real)	£/MWh	200	135	85

Table 1: Floating Wind Cost Estimates Over Time

4.1.2 From demonstration to commercial-scale projects

The floating wind industry is currently at the pre-commercial stage, with the first multi-unit 30MW demonstration project having been commissioned in Scotland in September 2017. Prior to this, deployment has been in the form of single unit prototypes and demonstration units. The cost for such small-scale deployments on the bases of per MW installed and per MWh produced is very high. Many of the costs incurred are disproportionate to the relatively small amount of capacity. Infrastructure projects such as floating wind require scale in order to reach cost and technical maturity.

Current demonstration sites of ~30MW have LCOE estimates ~£200/MWh. Larger, but still pre-commercial, sites of ~100MW have estimated LCOE of ~£135/MWh. LCOE for first commercial-scale floating projects is estimated at ~£85/MWh, with cost reductions driven mainly by: economies of scale in moving from ~5 units to 30+ units (minimum 300MW), thus rationalising the fixed cost base; and improved commercial and technical terms, particularly in reduced risk premium in overall cost of capital and prices charged by OEM's as well as higher capacity factors and longer project life.

These initial, significant cost reductions are driven mostly by individual project scale rather than overall deployment volumes as shown in Figure 2.

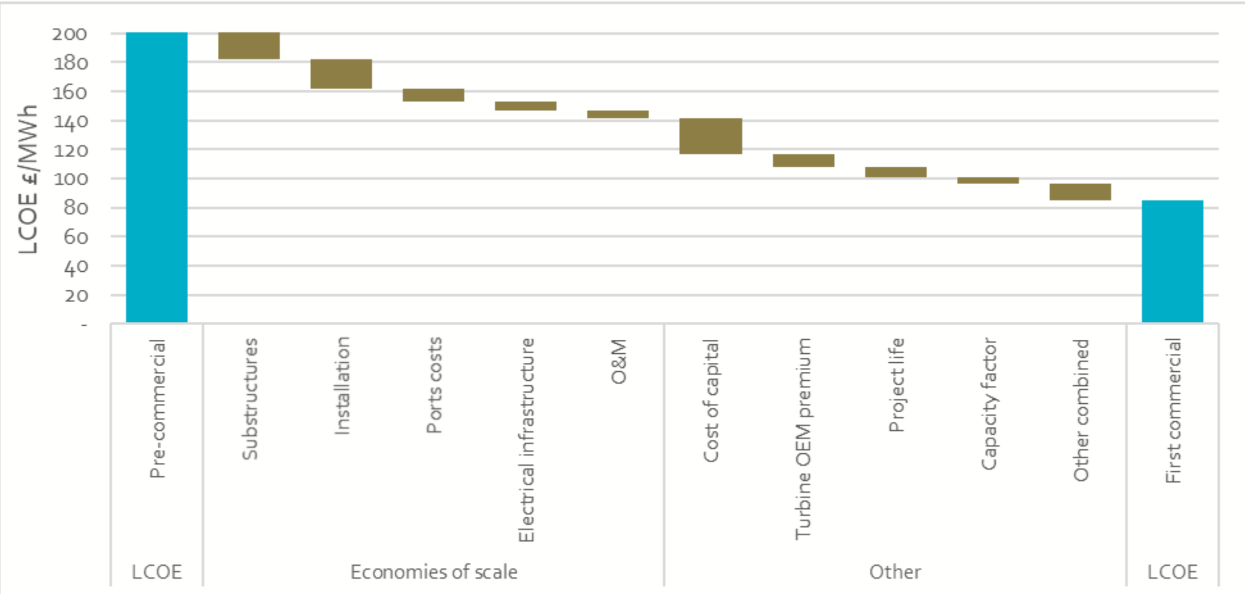

Figure 2: Floating wind cost reduction drivers from Pre-commercial to First Commercial Projects

4.1.3 From first commercial to mature commercial projects

Once floating wind projects are being deployed at commercial scale, cost reductions will be more incremental in nature and can be modelled using learning rates, which estimate a % reduction in cost for each doubling in capacity. The speed of cost reduction over time will therefore depend on the rate of global deployment.

Based on first commercial-scale floating windfarms with LCOE £85/MWh (approximate strike price £93/MWh) being commissioned in 2027 and applying a 13% learning rate[7], total global deployment of approximately 6GW would be required to reduce floating wind costs to the same level as the forecast UK wholesale electricity price and overall offshore wind costs. Global deployment of 1GW per year from 2027 to 2030 and 2GW per year from 2031 to 2050 would achieve this cost parity by 2031. Using this basis, estimated floating wind 15-year strike prices (to put costs in a UK context) are shown in Figure 3 in the context of historic and estimated future bottom-fixed offshore wind strike prices and against BEIS reference wholesale electricity price[8].

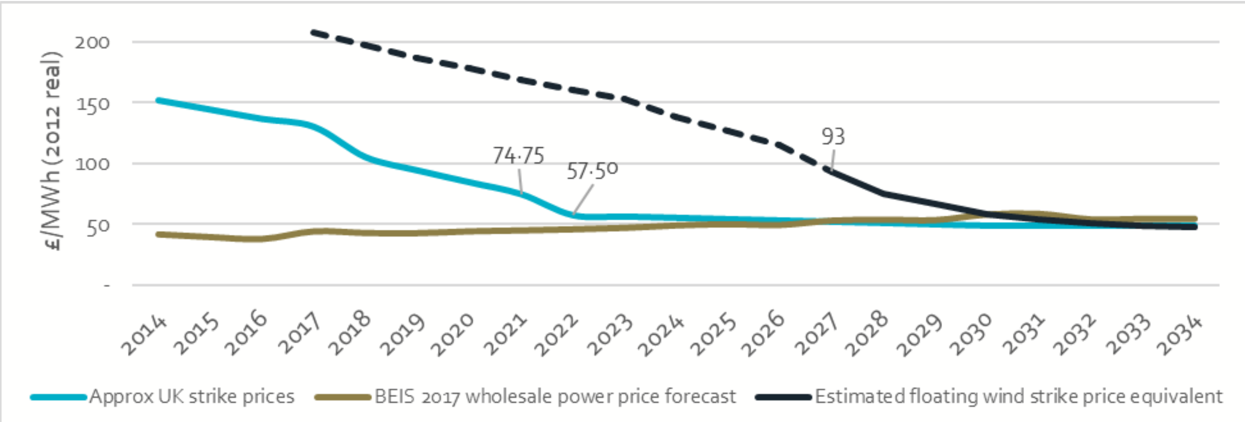

Figure 3: Estimated strike prices for floating wind, bottom-fixed wind and UK wholesale power price

These estimates show offshore wind, on its current cost reduction trajectory, reaching parity with UK wholesale prices by ~2027 and floating wind reaching parity around 2031. This shows floating wind costs "catching up" rapidly with bottom-fixed wind, which demonstrates both the amount of cross-over between the cost bases of floating and bottom-fixed offshore wind (eg. floating wind projects will use the same turbines (or with minor modifications) as bottom-fixed projects, apply similar project management processes and employ similar maintenance strategies) and the state of the art of technology to be applied in first commercial floating wind projects compared to early bottom-fixed projects. For example:

a. the first commercial floating wind projects will use minimum 8MW or 10MW turbines depending on timing compared to 2 – 3MW turbines in early bottom-fixed projects;

b. the first commercial floating wind projects will have access to relatively low cost of capital (estimated ~7% WACC) compared to WACC of ~10% for early bottom-fixed projects; and

[7] A Review of Learning Rates for Electricity Supply Technologies
https://www.cmu.edu/epp/iecm/rubin/PDF%20files/2015/Rubin_et_al_Areviewoflearningrates_EnergyPolicy2015.pdf

[8] BEIS 2017 Updated Energy & Emissions Projections – Annex M
https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2017

c. turbine and balance of plant maintenance strategies have matured significantly and will be applied in floating wind projects without the need for significant initial learning

The current stage of floating wind demonstration projects is performing the same role as small-scale projects in the early days of offshore wind (1990's globally and 2000's in the UK). From both the UK and global perspective, floating wind will become just one form of ongoing offshore wind deployment, following the trend for large-scale (300MW+) commercial sites, without the need to re-prove the marinization of core turbine technology.

4.2 Global Floating Wind Deployment

4.2.1 Global Offshore Wind Trends

Global offshore wind capacity has ramped up from 5MW in 1991 to 18.8GW installed by Q1 2018. Early rates of deployment were low by today's standards, with annual average installation rate of less than 10MW per year to reach 86MW by 2000 as core turbine technology and marine installation and operating strategies were tested and demonstrated. Horns Rev 1 at 160MW was the first 100MW+ offshore windfarm and only in the late 2000's did 100MW+ windfarms become commonplace.

In the period 2010 – 2017, annual deployment rates have been roughly 2GW per year as the value of offshore wind as an increasing part of the energy mix has been recognised by governments and industry. In the same period the average commercial-scale windfarm size in Europe has increased to over 300MW.

4.2.1 Global Offshore Wind Outlook

Bloomberg New Energy Finance (BNEF) and the IEA's Energy Technology Perspectives (ETP) Two Degrees scenario forecast 110 – 115GW of offshore wind globally by 2030. The ETP scenario further shows a pathway to 320GW by 2050. The global annual and cumulative offshore wind deployment in the ETP scenario is shown in Figure 4.

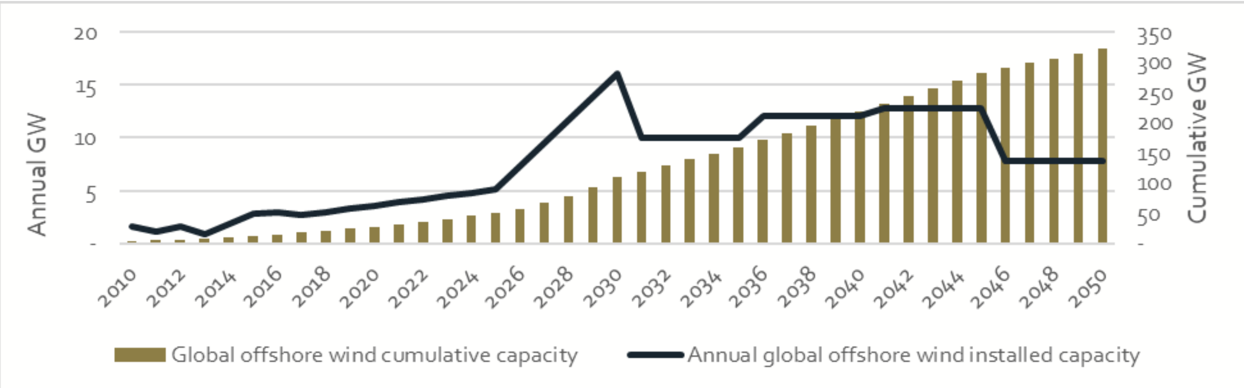

Figure 4: Cumulative and annual offshore wind deployment – ETP 2 degrees scenario

These forecasts imply average annual build-out rates for global offshore wind of 8.1GW to 11GW per year. Together with assumptions for the UK reaching 30GW by 2030 and 50GW by 2050, gives annual build-out rates for the UK and rest of the world (ROW) as shown in Table 2:

Offshore Wind Forecast Average Annual Build-Out Rates	2021 - 2030	2031 - 2040	2041 - 2050
UK	1.9GW	1.0GW	1.0GW
ROW	6.2GW	10.0GW	9.3GW
Global Total	**8.1GW**	**11.0GW**	**10.3GW**

Table 2: Average global offshore wind annual build-out rates

4.2.2 Global Floating Wind Outlook

There is currently 48MW of floating wind demonstration devices in the water globally, comprised of 30MW in the UK, 16MW in Japan and 2MW in Norway. As described in the Introduction to this report, globally, there are a number of floating wind markets in active development. Our analysis has identified 10.5GW of projects in the early stages of planning plus a further 6GW of floating wind development zones. While the exact timing and routes to market are not yet clear, floating wind is increasingly included in national planning and industry ambition. Equinor (formerly Statoil) has estimated that globally there could be 13GW of floating wind installed by 2030[9], including 3.5GW in Japan, 2.9GW in France, 2GW in the USA and 1.9GW in the UK and Ireland. This view is similar to that expressed by the Carbon Trust in the Floating Wind Joint Industry Project Phase I Summary Report[10], which expects up to 12GW of floating wind (out of ambition of 29GW from identified national industry and government bodies) to be feasible by 2030. The following national government or industry targets are particularly relevant to the near-term deployment of floating wind:

- Japan - Japan Wind Power Association[11] targets 10GW of offshore wind by 2030 and 37GW by 2050, including 4GW of floating wind by 2030 and 18GW by 2050.
- South Korea – the government has a published target[12] of 2% of electricity generation to come from wind power by 2035. Considering planned onshore and offshore wind deployment implies a requirement for additional capacity of 1GW by 2030 and 3.4GW by 2035. In June 2018, Swedish

[9] https://www.statoil.com/en/what-we-do/hywind-where-the-wind-takes-us/the-market-outlook-for-floating-offshore-wind.html
[10] https://www.carbontrust.com/media/675868/flw-jip-summaryreport-phase1.pdf
[11] http://jwpa.jp/englishsite/jwpa/vision.html
[12] Ministry of Trade, Industry and Energy (MOTIE), 9 September 2014 http://www.motie.go.kr/motie/ne/rt/press/bbs/bbsView.do?bbs_seq_n=79321&bbs_cd_n=16

company Hexicon AB received a Korean government grant to adapt platforms to local conditions, with a view to enabling serial production of turbine platforms in Korean shipyards.

- Taiwan - the government has announced the 1,000 wind turbines project, planning for 600 offshore and 400 onshore wind turbines by 2030. Total feasible offshore wind resource in 50 – 100m water depth for Taiwan has been estimated at 9GW[13] and country targets include construction of 520MW of offshore wind by 2020 and 4GW by 2030. 1GW of the 4GW by 2030 is planned to be floating wind.

- Norway – in December 2017, parliament approved a resolution calling for one or more floating wind demonstration projects, with the focus more on demonstrating the Norwegian offshore industry's capability in this sector, rather than generating electricity for the grid.

- France - the government's Plan de programmation pluriannuelle de l'Energie (PPE) set targets for offshore wind energy capacity of 500 MW by 2018, 3,000 MW by 2023 with a further 6,000MW awarded for installation beyond 2023[14]. The industrial opportunity presented by floating wind, deep waters and rocky seabed close to shore in many good wind resource locations and the delays in moving forward the planned Tender Rounds 1 and 2 bottom-fixed projects make floating wind deployment highly attractive to France.

- USA - The US Department of Energy (DOE) Wind Vision[15] expects the USA to have installed 22GW of offshore wind by 2030 and 86GW by 2050. This will require a significant ramp-up of activity in a very short space of time in a market which has not yet developed a bottom-fixed offshore wind industry, but which has a long history of offshore oil & gas and a wealth of potential deep-water sites.

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[13] https://www.mofa.gov.tw/Upload/RelFile/2508/111034/25bcd458-67d7-4ed4-994b-128a7ba49d17.pdf

[14] https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000033312688&dateTexte=&categorieLien=id

[15] https://www.energy.gov/sites/prod/files/WindVision_Report_final.pdf

In the longer term, our country-by-country analysis indicates that global floating wind deployment in key geographies, excluding the UK, could reach up to 95GW as shown in Figure 2.

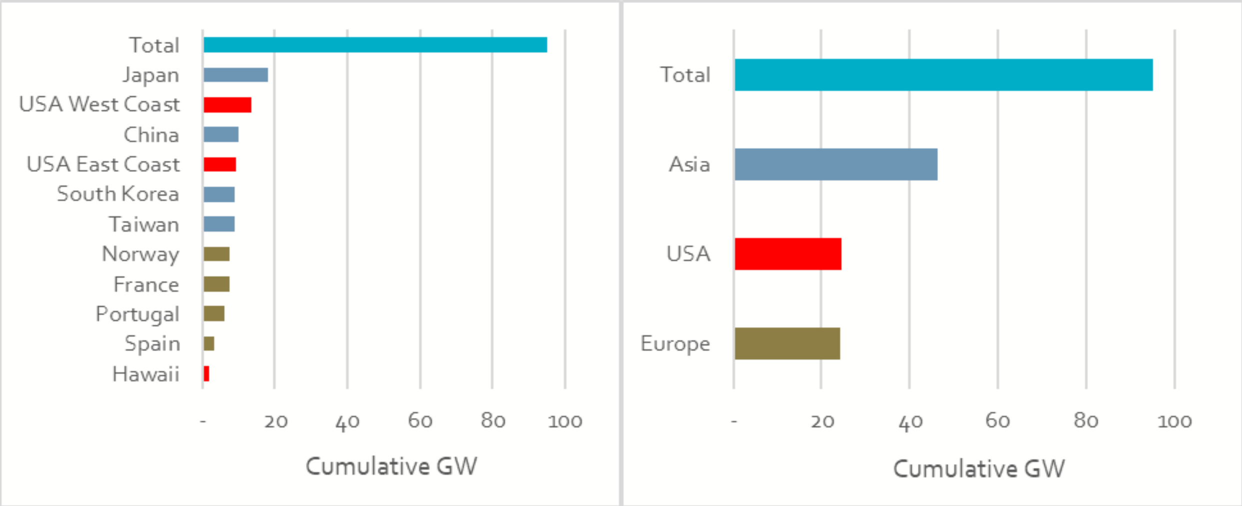


Figure 5: Potential 2050 floating wind deployment shown by country and by region

4.2.3 Floating Wind Deployment Assumptions for ROW (non-UK)

Based on the continuing growth of global offshore wind deployment and the preference for floating wind (or at least lack of preference for bottom-fixed wind) in many emerging markets, and taking into account the estimated cost trajectory, the following base case deployment profile for commercial-scale floating wind has been assumed for modelling in this study:

- Conservatively assume no commercial-scale floating wind deployment before 2027;
- Annual build-out rate of 1GW per year in ROW from 2027 to 2030, reaching 4GW installed commercial-scale floating wind by 2030;
- Annual build-out rate of 2GW per year after 2030, to reach 24GW by 2040 and 44GW by 2050.

This profile of floating wind deployment is shown in Figure 6 as a proportion of total ROW offshore wind deployment.

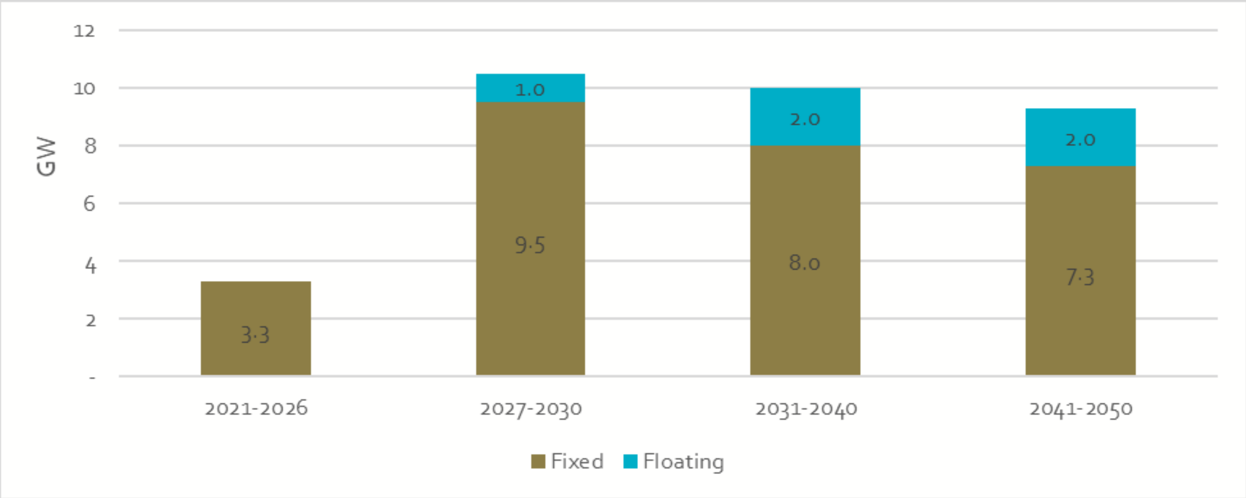


Figure 6: ROW average annual floating and bottom-fixed offshore wind deployment

With these assumptions:

- Floating wind will represent 9% of ROW annual deployment from 2027 – 2030; 20% from 2031 – 2040; and 22% from 2041 – 2050.
- Floating wind will represent 5% of ROW cumulative installed offshore wind capacity by 2030; 13% by 2040 and 16% by 2050.

This deployment in ROW is expected to come from the markets highlighted. ROW cumulative floating wind deployment is shown as a function of total ROW offshore wind deployment in Figure 7.

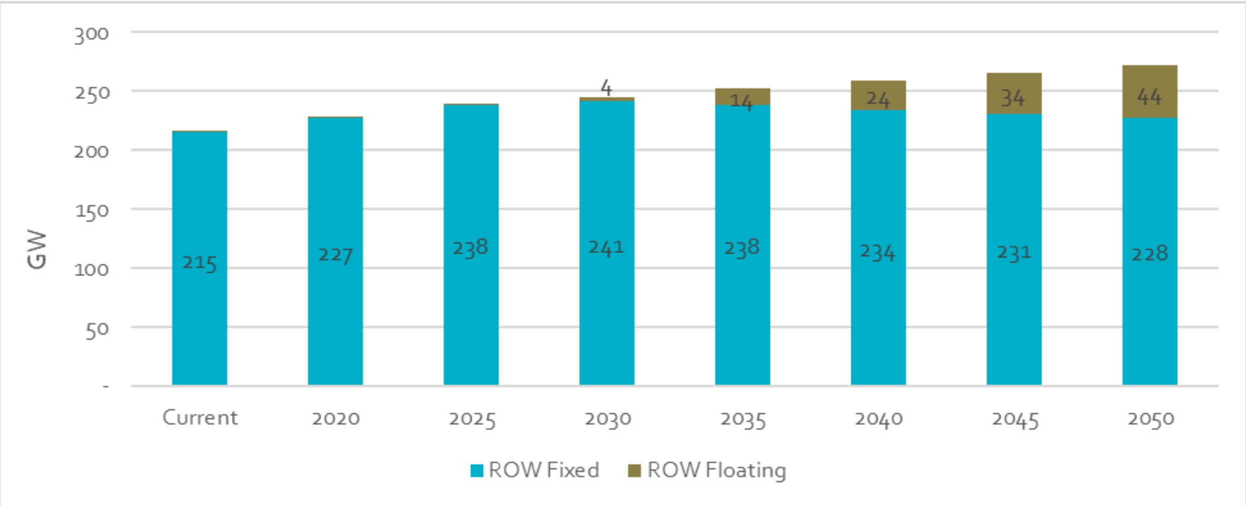


Figure 7: ROW Floating and Bottom-Fixed Offshore Wind Cumulative Deployment

Note that the assumption of 4GW of floating wind by 2030 and 44GW by 2050 are less than 40% of the Equinor forecast of 13GW (11GW excluding the UK) and 46% of our estimated full potential of 95GW for the same time periods, implying significant room for upside in the forecast used in this study.

4.3 ROW Floating Wind Market Value

4.3.1 Base Case

With the above cost assumptions and conservative assumption of 2GW installed per year in ROW from 2031, the floating wind market in ROW will have an annual value of £5.8bn and be worth a cumulative £122bn by 2050, as shown in Figure 8.

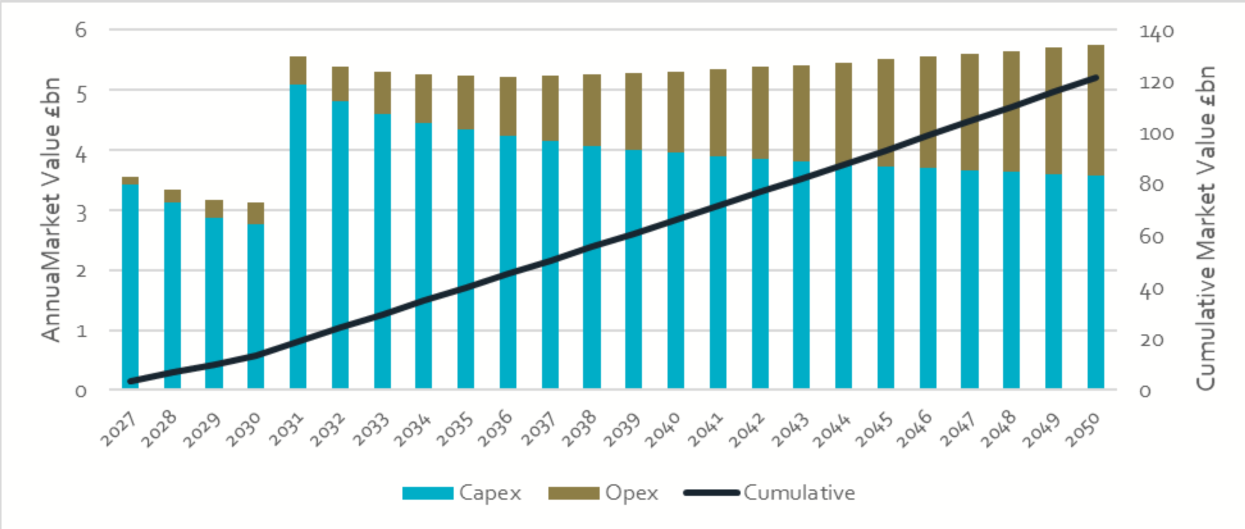


Figure 8: Base Case - Annual and cumulative value of ROW floating wind market to 2050

4.3.2 High Case

In a high deployment case where the ROW market can achieve the estimated potential of 95GW by 2050, this implies 4.5GW installed annually in ROW from 2031 to 2050, which would be ~47% of annual offshore wind installations in ROW. With floating wind costs expected to converge with costs of bottom-fixed wind by 2031, it is reasonable to assume that floating wind projects will capture an increasing share of the offshore wind market. Floating wind, with 95GW installed would represent 35% of ROW cumulative installed capacity by 2050.

In this high case, the floating wind market in ROW will have an annual value of £11.5bn and be worth a cumulative £231bn by 2050, as shown in Figure 9.

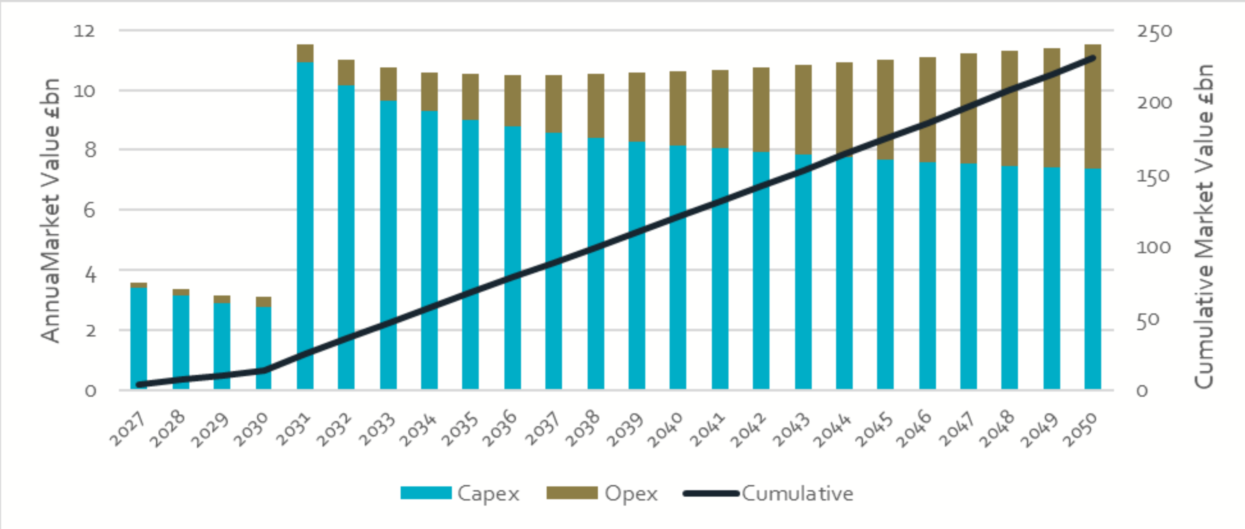


Figure 9: High Case - Annual and cumulative value of ROW floating wind market to 2050

4.4 UK Floating Wind Deployment

4.4.1 UK Offshore Wind Trends

Similar to the global picture, UK offshore wind deployment started small with the 4MW Blyth project commissioned in 2000. By 2010, 233MW had been installed in UK waters. In the period 2011 to 2017, a further 6GW has been installed, with an average annual build-out rate of 850MW per year. At the end of Q1 2018, the UK has the world's largest installed capacity (6.6GW) of offshore wind with 35% of the global total, a position expected to be maintained until at least 2020.

4.4.1 UK Offshore Wind Outlook

The UK government has recently announced auctions to be held "around every two years" from May 2019 which will deliver between 1GW and 2GW per year of offshore wind throughout the 2020's, implying installed capacity of up to 30GW by 2030. This provides increased visibility to project developers, investors and supply chain companies on the size and timing of market requirements and has been welcomed for providing added certainty for offshore wind and other forms of renewable energy.

The UK industry has recently unveiled plans for a sector deal, which aims for 30GW of capacity by 2030 and 50GW (but with ambition for up to 70GW) by 2050. These two timeframes are considered here separately.

With 14GW due to be installed by 2023 and an existing consented pipeline of up to 32GW, the challenge of reaching 30GW installed by 2030 is likely to relate less to identifying sites for deployment and more to accessing the appropriate supply chain in a growing and highly competitive global market and the ability to obtain funding in time to install 16GW over 2024 – 2030. However, the inclusion of floating wind sites in upcoming leasing rounds would provide further options for deployment and broaden the supply chain which is able to contribute to doubling UK offshore capacity over 7 years.

From 2030 – 2050, the larger challenge will be access to sufficient sites to achieve upwards of 50GW. There is no definitive view on the limit to economically exploitable bottom-fixed offshore wind sites in UK waters. The Energy Technologies Institute (ETI) has suggested that even 40GW of UK offshore wind could include 8-16GW of floating wind and 55GW could see as much as 27.5GW of floating wind[16]. The industry's sector deal proposal includes floating wind as a key element of the innovation strand, highlighting its importance in unlocking the full potential of UK offshore wind.

Assuming steady rates of deployment, the sector deal ambition of 30GW by 2030 and 50GW by 2050 will require annual offshore wind build-out rates of 2.3GW from 2024 to 2030 and 1GW from 2031 to 2050. This is shown in Figure 10, which also shows the increase in annual deployment to 2GW from 2031 required to meet the upper end of the deal ambition of 70GW by 2050.

Figure 10: UK Offshore Wind Annual Deployment Forecast

4.4.2 UK Floating Wind Deployment Assumptions

The level of UK deployment of floating wind will depend on appetite for further expansion of the offshore wind sector. To inform the Scenarios Analysis in Section 7 we have generated 3 deployment scenarios.

An easily achievable base case is that the UK will deploy 10GW of floating wind between 2030 and 2050 (an average of 500MW per year) to contribute to achieving the sector deal proposal base case of 50GW – this assumption is used to build up our central scenario (see Section 7). This is consistent with floating wind reaching cost parity with the UK wholesale electricity price by 2031, even with conservative assumptions on global deployment, meaning that floating and bottom-fixed sites are likely to win a roughly equal share of capacity.

[16] https://www.imeche.org/news/news-article/feature-a-floating-future-for-wind

In a scenario (see Section 7, Scenario 1) where there is proactive support for the development of UK floating wind, 20GW of floating wind could potentially be achieved (pushing the industry towards the upper end of ambitions of 70GW) by 2050.

ORE Catapult expect that industry ambition will in fact stretch to 70GW by 2050 because UK annual electricity demand is set to increase from 330TWh today to at least 390TWh per year by 2050[17] (equivalent to roughly 90GW of offshore wind capacity) and offshore wind is already one of the lowest cost forms of large-scale electricity generation.

It is also worth noting that achieving 50GW by 2050 implies deploying only 1GW per year from 2031 to 2050 between bottom fixed and floating wind. In this case, the UK will form a decreasing proportion of the global annual construction market as shown in Figure 7. This makes it less likely that the UK will be able to continue to attract increasing levels of investment from overseas companies who would establish operations and create value in the UK with a larger ongoing market.

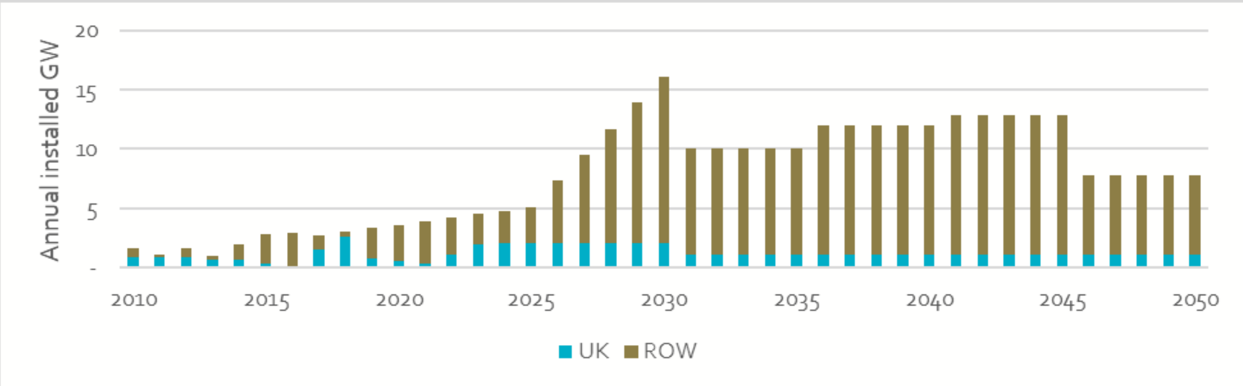


Figure 11: UK share of annual offshore wind installation

This all represents a real opportunity for floating wind in the UK:

- Realising the upper end of industry ambition of 70GW could require upwards of 20GW of floating wind, which is 100% greater than the assumed base case of 10GW by 2050;
- More UK floating wind will increase the UK's share of the annual offshore wind construction market, making the UK more attractive as a hub for supply chain companies, increasing the potential for UK content and value, and increasing the utilisation of port facilities

4.5 UK Floating Wind Market Value

4.5.1 Base Case

The cost modelling shows floating wind costs converging with bottom-fixed wind and wholesale power price by 2031. In a scenario where the UK will only deploy cost-competitive generation technologies, this

[17] National Grid Future Energy Scenarios – 2 degrees scenario

convergence is the natural point at which floating wind can successfully compete on cost for capacity in the UK.

We should therefore expect to see floating wind deployed in the UK post-2030, whether or not public support is provided for the early stages of UK deployment. However, it is the public and private actions to be taken now in terms of supply chain and market development, which will determine the value which the UK can realise from a growing global and domestic market.

With the above cost assumptions and conservative assumption of 500MW of floating wind installed per year in the UK from 2031, the floating wind market in the UK will have an annual value of £1.3bn and be worth a cumulative £26bn by 2050, as shown in Figure 12.

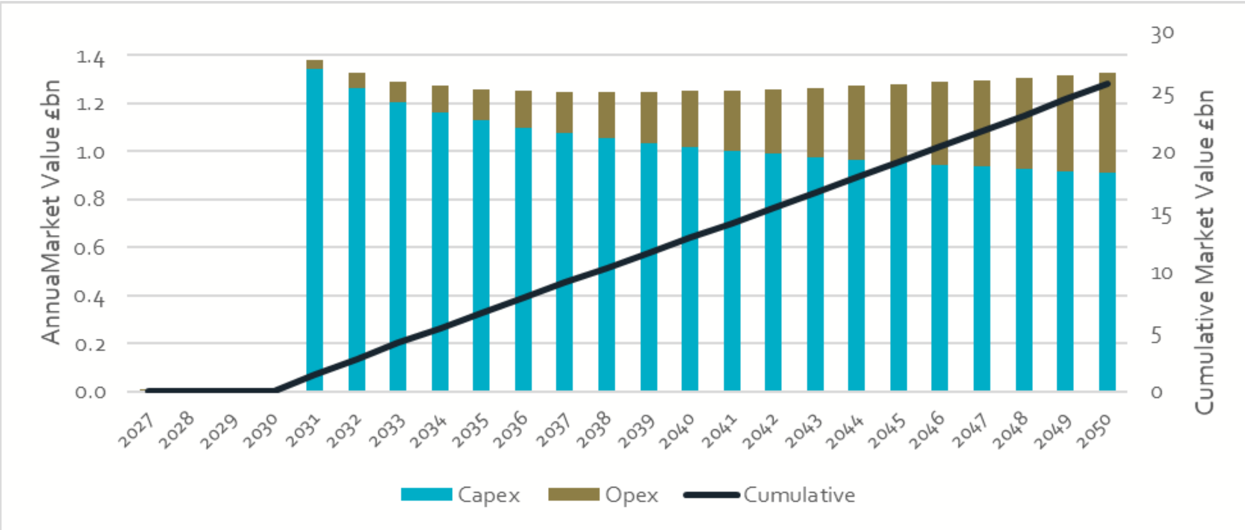


Figure 12: Base Case Annual and cumulative value of UK floating wind market to 2050

4.5.2 High Case

In a high case, with an average annual deployment rate of 1GW of floating wind per year from 2031 to 2050, the floating wind market in the UK will have an annual value of £2.8bn and be worth a cumulative £56bn by 2050, as shown in Figure 13.

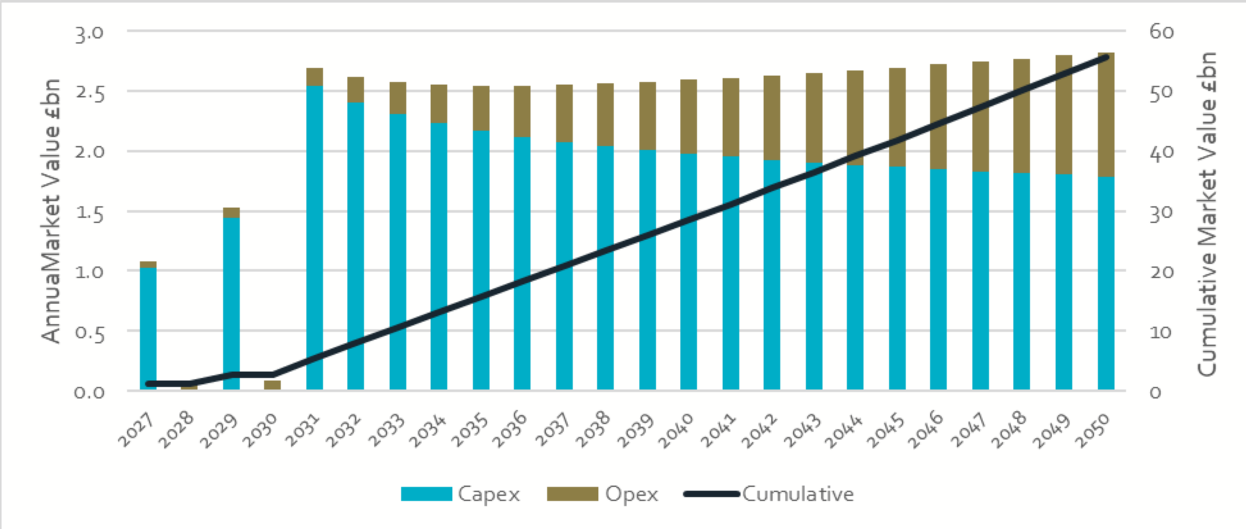


Figure 13: High Case Annual and cumulative value of UK floating wind market to 2050

4.6 Market Size Summary

Taken together, these cost and deployment assumptions for the UK and ROW show an annual market value by 2030 of £3.1bn in the base case to £3.2bn in the high case and by 2050 of £7.1bn in the base case to £14.3bn in a high case, with cumulative value to 2050 of £147bn in the base case to £287bn in the high case. The annual values are shown in Figure 14.

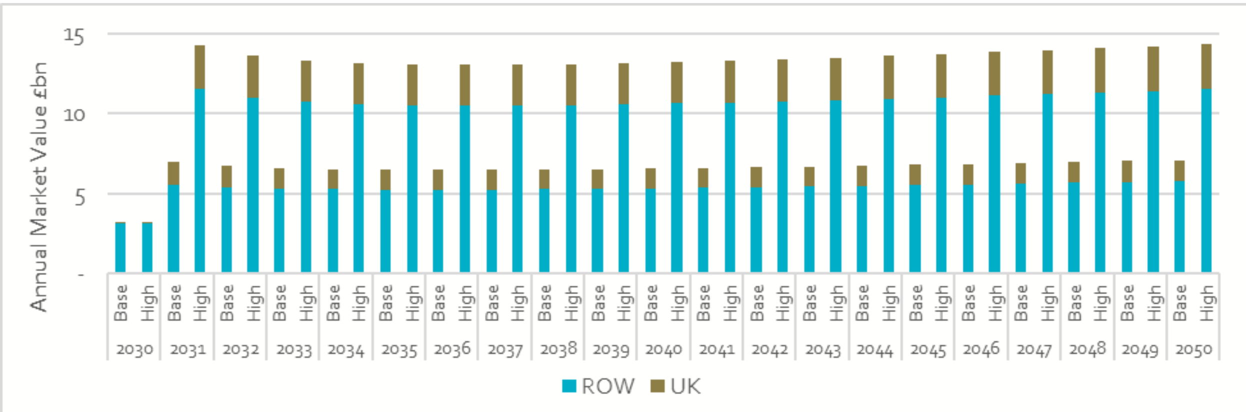


Figure 14: Global floating wind annual market value for Base Case and High Case

5 UK Content and Potential Value

The value which the UK can realise from floating wind depends on the portion of the domestic and global export markets captured by the UK supply chain. Analysis has been carried out on each key supply chain segment, based on an understanding of where UK offshore wind has reached to date and the prospects with enhanced supply chain investment. The detailed supply chain assessment, specifying where UK companies are active in relevant sectors and have existing expertise, and how this translates to potential domestic and export market share, is included in Appendix 4.

5.1 UK Supply Chain Commercial Readiness and Required Investment

The UK supply chain in almost all areas is assessed as being ready, or having a clear path to readiness, for commercial-scale floating wind projects. For these segments, UK companies have the ability to service the domestic and export market, either using current facilities and products or by continuing with current product development and making investments which they can fund themselves or with minimal assistance.

The notable exceptions to this are Substructure Fabrication and Ports & Logistics, which are assessed as having no clear route to being ready to handle commercial-scale deployments (see Appendix 4, Sections 2 and 7). For Substructure Fabrication, this highlights a direct need for focused development and support in an area considered to have strong domestic market share potential. For Ports & Logistics, while the share of lifetime cost is relatively low (4% combined), development of key UK ports is crucial to the development of the floating wind industry in the UK as access to suitable port facilities will be necessary to enable substructure fabrication and O&M major repair tasks to be carried out locally (see Appendix 4, Section 10). Development of appropriate port facilities, including suitable quayside water depths, will be critical in order to unlock the UK's potential share of 40% of the lifetime project value. The case studies in Boxes 1 to 4 illustrate some of the potential in these supply chain segments.

Box 1: Case Study - Global Energy Group

Global Energy Group (GEG) provides construction, maintenance and decommissioning solutions to a range of energy industry customers. With a core background in oil & gas, GEG has been involved in a number of renewable energy projects, including fabrication of monopile foundations for the Scroby Sands offshore windfarm, jacket foundations for the Beatrice offshore demonstrator and the suction anchor buckets for the Hywind Scotland project. GEG has facilities in North East Scotland, including Nigg Energy Park. Nigg has a 332,000m² construction yard with 36,000m² of covered fabrication space and 900 metres of heavy load-bearing quayside. To be fully ready to fabricate substructures for commercial-scale floating wind, GEG requires investment in the tens of millions of pounds in heavy rolling and handling equipment, welding equipment and personnel and new buildings. This could utilise up to 200 additional employees and provide a welcome boost to employment in the area.

Box 2: Case Study - Kishorn Port and Dry Dock

In preparation of the construction of substructures for floating offshore wind projects in Scotland, the dry dock has been refurbished after being out of use for 23 years. It is estimated that 22 direct jobs have been created in the construction works and additional employment will be created in the on-site quarry which is being operated by supplier Leith. Wester Ross is an area with little industry and employment opportunities, therefore, this is already an improvement to the area.

A visible long-term pipeline of work is required in order to safeguard the facility and related jobs in this rural area.

Box 3: Case Study - Hunterston PARC

Hunterston PARC has been identified as a national piece of infrastructure for offshore wind (National Renewables Infrastructure Plan). The PARC has 120 hectares of land with suitable infrastructure available for manufacturing activities, a drydock of 230 x 150 metres, quayside water depth of 22 metres, and an extensive, sheltered marine area for storage and erection activity in water over 60 metres deep. It has its own rail terminals and is located close to Glasgow. With a clear line of sight to a pipeline of floating wind projects, the owners have the willingness and financial strength to turn plans for a hub of floating wind activity into reality, including the refurbishment of the drydock and construction of a heavyweight logistics jetty.

Box 4: Case Study - Milford Haven Port Authority (MHPA)

The Port of Milford Haven is the UK's largest energy port, and the largest port in Wales. The port is situated in close proximity to deep water, with strong offshore wind resource, extensive high-skill supply chain and transmission grade infrastructure able to accommodate GWs of capacity. The port and its supply chain evolved around the oil and gas sector originally comprising of 5 active refineries and now comprising one operational refinery, two terminals, the 2.2GW CCGT power station and two LNG terminals.

The majority of employment and economic benefit revolves around Valero, one of the largest refineries in Western Europe. Whilst significant investment is taking place in Valero, if this refinery were to close, it would have a significant impact on other businesses and overall economic activity of Wales.

The Port of Milford Haven is actively diversifying its interests and has a keen focus on marine renewables. Floating wind is a key line being pursued and MHPA has worked with different floating wind technology developers to ensure the port is made suitable for deploying large floating wind arrays. The necessary upgrades could be completed by 2022/23 and, depending on the size of pipeline expected, investment of £50-80m would be required. The majority of the funding could be made available via the pending Swansea Bay City Deal.

The port could act as a one stop shop for fabrication, assembly and O&M, bringing in near-by facilities to support the space needs for large commercial-scale floating wind projects when required. The close proximity to Port Talbot for steel and Swansea's turbine handling experience add to the attractiveness of Pembrokeshire as part of the Swansea Bay Region to the floating wind sector. Bristol or Belfast could also take a share of the activity. This could offer significant economic opportunities for a number of businesses and towns under a single development.

Supply chain stakeholders have provided input to the levels of investment required to enable them to service what they consider to be an achievable share of a global market of 1GW, 2GW and 3GW per year by 2030, including up to 1GW in the UK. The responses showed minimal difference between ambition and investment requirements for a global market of 2GW compared to 3GW per year. The input received relating to a global market of 2-3GW per year is summarised in Table 3.

Supply chain	Activities	Investment	Additional Jobs	Annual order value required	Support Required
Design	Development Services (PM, Development and Consenting, Surveys, Certification)	£12m	430	£40m	Internal funding; Existing public sources
Manufacture	Substructure (steel or concrete including substation)	£300m	670	£135m	Internal funding; Existing public sources; Political support; Significant public investment
	Wind turbine				
	Anchors	£1m	<100	£2m	Internal funding
	Mooring lines				
	Electrical infrastructure				
Assembly	Ports & Logistics	£400m	1,100	£60m	Internal funding; Existing public sources; Political support; Significant public investment
	Cranes				
Installation	Vessels and subsea engineering	£170m	670	£200m	Internal funding; Existing public
O&M	Major & minor repairs	Note some overlap with Installation and Ports & Logistics			
Decom	Decommissioning				
Total		**£883m**	**3,300**	**£502m**	

Table 3: Maximum estimated supply chain investment

Examples of some of the companies already active in supplying into floating wind projects or developing solutions suitable for floating wind are given in Boxes 5 to 8.

Box 5: Case Study - Bruce Anchor

Bruce Anchor is a British company specialising in drag-embedded anchors and associated equipment design. Originally the company provided anchors for the oil and gas industry, but has since successfully diversified into offshore renewables, and has been involved in wave energy and multiple floating offshore wind projects both in the UK and abroad, particularly in Japan.

Oil & gas industry anchoring solutions available today are adequate to support the renewable energy industry but carry high costs and may under perform in certain locations, and so Bruce Anchor is developing a drag-embedded anchor specifically for floating offshore wind. This anchor will be able to provide the same holding capacity as bigger units, but at a significantly reduced weight and, as the consequence of reduced weight, at a fraction of the transportation costs. This innovation will also allow for smaller and hence cheaper vessels to be used for mooring system installation, hence lowering the cost of energy of floating wind.

Whilst Bruce Anchor only designs drag-embedded anchors and associated equipment and subcontract their fabrication, around 90% of fabrication is performed in Sheffield using a mix of British and European steel. Together with facilities in Stoke, sufficient quantities of drag-embedded anchors could be made in the UK to meet all internal market requirements and as well as to export anchors abroad.

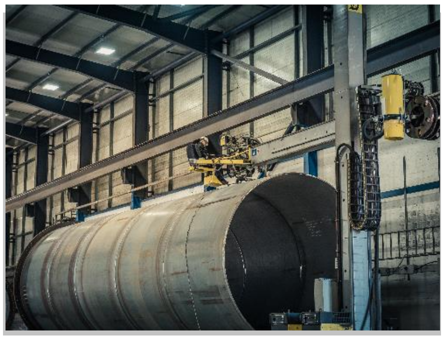
Box 6: Case Study - JDR Cables

JDR designs, engineers and manufactures subsea power cables, production umbilicals, intervention workover control systems and end terminations and accessories. The company made significant investment in new facilities in Hartlepool in 2009, which have since been expanded and upgraded. JDR has provided cable solutions to 5 UK and 3 overseas offshore windfarms as well as WaveHub in the South West of England.

In June 2017, JDR was selected by WindPlus as the preferred cable supplier for the Windfloat Atlantic (WFA) 25MW floating wind farm. The project – located off the coast of Northern Portugal – will see the industry's first application of dynamic cables operating at 66kV. The scope of supply includes the design and manufacture of array cables to suit V164 floating turbines. To support the project, JDR has designed a unique, easy to install, dynamic cable break-away system, which protects the floating platform in the unlikely event of a mooring line failure.

Box 7: Case Study - CSWind

CSWind UK is the UK's only established manufacturer of large scale wind turbine towers. It has previously and is currently fabricating tower sections for such large projects as London Array, Beatrice and Hornsea wind farms. The company currently produces 6 offshore wind turbine tower sections a week. This could be increased to 10 by growing the headcount.



In addition to employing local population for tower fabrication, CSWind sources internal components from UK companies where possible and uses local companies for support services and to transport steel and tower sections from and to the harbour, hence providing much needed employment opportunities in the rural area. An investment of approximately £3 million would be required to set up steel cutting and bevelling facilities which would allow the facility to include UK supplied steel in its supply chain.

CSWind can roll towers up to 7 m in diameter and store up to 100 tower sections. Both of these limitations can be expanded as the facilities are located on a 1,000-acre site. The location has the potential for additional investment in the infrastructure to keep pace with advances in the industry and enable transportation of tower sections of over 7 metres to the harbour, as well as to build a new hangar to handle tower sections larger than 7 metres.

Box 8: Case Study - Bridon Bekaert Ropes Group

Bridon Bekaert Ropes Group (BBRG) is a global manufacturer of ropes and cables. In the UK it has manufacturing facilities in Doncaster, Newcastle, Coatbridge (Glasgow), Grangemouth and a sales office in Aberdeen. BBRG supplies a range of solutions to the oil & gas, mining, shipping, industrial and other sectors. It increasingly views the offshore renewable sector (floating wind, tidal energy and wave energy) as an important destination for its technology.

BBRG's global supply of synthetic rope products are predominantly produced within two manufacturing sites in Scotland (Coatbridge and Grangemouth). These products are well suited to the construction and mooring of renewable energy systems in general specifically floating wind. Whilst some opportunities are served by existing products, BBRG is continuing to invest heavily in the development of alternative products which address the technical, economic and scaling challenges of floating wind and which will be exclusively manufactured in their Scottish facilities. Both facilities provide manufacturing jobs and a revenue stream for local logistics firms in areas which have been subjected to economic uncertainty and job losses in recent years.

5.2 UK Supply Chain Potential

In conducting this study, supply chain benchmarking on cost and quality has been undertaken through online surveys of technology developers and project developers. The key finding on quality was that UK companies compare favourably with international competitors in all areas. On cost, UK supply chain was considered cost-competitive in all areas except fabrication and assembly of substructures and supply of anchors and moorings. The most competitive pricing in these key areas has been found in China, Korea, Poland, Spain, Belgium, Netherlands, Singapore and Taiwan. In addition to providing more competitive pricing, key areas for improvement were highlighted as ability to meet volume requirements and time constraints.

From this analysis and with critical input from the industry workshop, estimates have been developed for:

- The maximum potential UK share of the domestic and export markets - this level of potential will only be achieved with the appropriate public policy and private measures, including the investments highlighted, above, to develop the UK floating wind market and supply chain (these policy measures will be analysed in the following section); and
- A scenario where the UK does not proactively pursue floating wind and effectively follows the market from 2031, by which point first movers have developed and demonstrated the relevant capabilities to dominate the global market.

These 2 sets of estimates of achievable UK market share are shown in Table 4 and highlight the expected benefits of being a first mover in a developing market compared to waiting until core capabilities have been developed elsewhere and export trends have been established. Reaching this full potential will require the actions and investments already highlighted in Table 3.

The most crucial difference between the two cases of maximum and minimum potential market shares is that with early strategic investment in ports and fabrication yards, construction of UK projects can be staged from UK ports, as can major O&M if repairs are to be carried out once towed back to a quayside, meaning much increased incentive to use the wider UK supply chain. As well as accelerating the rate of development of the existing indigenous supply chain, there will be greater logic for OEM's to establish UK bases, significantly increasing the opportunities for UK content in turbines. The economic hubs built up around Green Port Hull (including Siemens investment in blade manufacture), Barrow and Belfast are examples of how this is working in offshore wind. The right investments for floating wind can increase the UK content in all UK offshore wind projects due to this crowding-in effect.

Supply Chain Segment	Maximum Potential		Market Follower	
	UK Market	Export Market	UK Market	Export Market
Development Services (PM, Development and Consenting, Surveys, Certification)	80%	45%	39%	7%
Substructure (steel or concrete including substation)	60%	0%	15%	0%
Wind turbine	40%	0%	10%	0%
Anchors	50%	9%	15%	2%
Mooring lines	50%	9%	15%	2%
Electrical infrastructure	42%	1%	11%	1%
Ports & Logistics	75%	0%	19%	0%
Cranes	75%	0%	19%	0%
Vessels and subsea engineering	75%	25%	19%	11%
Other Capex	75%	15%	20%	4%
Capex (weighted by value)	**52%**	**4%**	**14%**	**1%**
Major & minor repairs	85%	20%	43%	7%
Other Opex	85%	20%	37%	4%
Opex (weighted by value)	**85%**	**20%**	**38%**	**6%**
Decommissioning	**60%**	**10%**	**15%**	**4%**
Lifetime	**65%**	**10%**	**22%**	**3%**

Table 4: UK Content Assumptions – High and Low

5.3 UK Potential Value

In a scenario where ROW floating wind follows the base case trajectory (44GW by 2050) and the UK is able to stimulate 20GW of UK deployment by 2050 (the high case outlined in Section 4.5.2) and capture the estimated maximum potential share of the domestic and export markets, the UK value created from floating wind is substantial. The UK supply chain has the potential to capture £2.3bn per year between 2031 and 2050. This would support £2bn GVA per year (cumulative £33.6bn by 2050) and more than 17,000 FTE (direct plus indirect) by 2050. The breakdown of the annual value capture is shown in Table 5.

UK 2050 Annual Value with Supply Chain reaching Maximum Potential	UK Market Value Capture (£m)	Export Market Value Capture (£m)	GVA (£m)	FTE
Development Services (PM, Development and Consenting, Surveys, Certification)	109	113	239	2,820
Substructure (steel or concrete including substation)	156	-	121	920
Wind turbine	298	-	177	1,210
Anchors	2	1	2	20
Mooring lines	19	7	15	110
Electrical infrastructure	131	7	109	1,390
Ports & Logistics	35	-	33	280
Cranes	7	-	7	60
Vessels and subsea engineering	36	24	53	500
Other Capex	129	51	141	1,080
Capex Total	**922**	**133**	**895**	**8,370**
Major & minor repairs	468	232	613	5,800
Other Opex	410	45	434	2,740
Opex Total	**878**	**277**	**1,047**	**8,540**
Total	**1,800**	**479**	**1,941**	**16,910**

Table 5: Market Value Capture, GVA and Jobs Supported

Significantly, 50% (8,540) of the jobs supported will be in O&M and related services and 17% (2,820) in Development, Design and PM. These are highly exportable services and can build strongly on existing UK expertise in both the offshore wind and oil & gas industries.

With a potential of roughly 17,000 jobs and £33.6bn of GVA supported, even with conservative global deployment of 2GW per year, it is critical to analyse the public policy support required to enable this value capture as well as assessing the impact of not supporting the early stages of UK floating wind deployment. This is done through policy and scenario analysis in the following sections, where our preferred Scenario 1 with proactive UK support for floating wind deployment results in the GVA and jobs figures stated here.

6 Policy Analysis

6.1 Policy Analysis Background

The purpose of the policy analysis is to identify and assess key public policy options for supporting the early stages of UK floating wind deployment, with the aim of creating maximum value for the UK. The analysis assesses the expected short-term and longer-term impacts of implementing different forms of support and considers factors which could pose risks to the effectiveness of these policies. The key factors driving the potential economic benefits to the UK are:

- Volume of UK and ROW deployment;
- UK content in domestic and export markets; and
- Rate of cost reduction;

UK policy can have a large, direct impact on UK deployment and UK content, an impact on cost reduction and very limited, if any, impact on ROW deployment. Policies are therefore assessed in terms of their expected impact on UK deployment, UK content and ability to export in order to understand potential for creating maximum value for the UK from a floating wind sector.

6.2 Policy Options

The support measures identified throughout this project via workshop and questionnaire industry engagement (see Appendix 2) as being most effective in supporting the early stages of UK floating wind deployment are:

- Availability of seabed rights for development of floating wind sites;
- Enhanced revenue support for at least 100 MW of pre-commercial UK projects in Scotland and/or the South West of England (in addition to the Hywind Scotland and Kincardine projects);
- Public co-investment with the private sector in strategic port assets and fabrication facilities; and
- Enhanced revenue support for the first commercial-scale projects to maintain the UK's lead in floating wind deployment, develop the UK supply chain and provide an option to use this as the foundation for a longer-term pipeline.

6.3 Potential Impact of UK Policy

6.3.1 Availability of seabed rights and project development for floating wind sites

With a typical timeline from site leasing to first power of seven years, the availability of seabed rights suitable for commercial-scale floating wind deployment is obviously necessary for the future development of the UK floating wind industry.

Short-term Impacts

The short-term implications of seabed rights are with the Crown Estate managers. The most pressing requirement for seabed rights is for at least one more test and demonstration scale (c.100MW) site in the UK. The Crown Estate continues to provide an open opportunity for projects to secure seabed rights for up to 100MW of capacity. The Crown Estate Scotland has now closed their process for test and demonstration applications.[18] We do note that there are existing seabed rights in the South West and Scotland which could potentially offer the opportunity for floating wind development.

Long-term Impacts

The longer-term success of a commercial scale installation is reliant upon availability of sites suitable for commercial-scale floating wind deployment. As above, the typical development timeline is 7 years and therefore to achieve the assumptions in this report of a commercial deployment by 2027 it will require a commercial scale agreement to be made around 2020. The Crown Estate and Crown Estate Scotland[19] have both announced potential offshore wind leasing for 2019. The Crown Estate has confirmed a max depth of 50m, but Crown Estate Scotland has not specified a maximum depth which indicates floating wind applications would be accepted as well as bottom fixed applications.

Cost of Support

The costs of seabed rights and leasing activities are born by the Crown Estate landlords and the Regulators in preparation. Site identification and feasibility assessments by developers is critical and they will incur costs in this process.

Risks and Mitigations

The main risk to the future UK economic value associated with accessing seabed rights is simply that if they are not made available in a way which allows commercial projects to be built, then it creates knock-on implications with consenting risk and the risk of winning a subsidy based on a competitive CFD process.

6.3.1 Revenue support for at least 100 MW of pre-commercial UK projects

The key reason for supporting at least one more UK pre-commercial scale project is to enable gradual scaling up of the domestic supply chain market (Appendix 2). The aim is to put UK companies and products at the forefront of the global market. They require a pathway from small-scale demonstration projects to commercial-scale projects. This support would ultimately accelerate the deployment of larger-scale projects (with a reduced development timeframe compared to fully commercial-scale).

Funding more than one further pre-commercial project will incur additional cost, but will also provide more opportunities for technology and supply chain development as well as further geographic development (for example siting projects in the South West of England and Scotland). The long-term value to the UK will by greatly enhanced by selecting floating technologies for pre-commercial projects

[18] Crown Estate Scotland - New offshore wind leasing for Scotland, discussion document, May 2018
[19] Ibid

which are best suited to prevailing UK site conditions and for which the UK supply chain can focus on developing particular expertise.

This option would see a subsidy mechanism made available at an enhanced (capped) rate for at least one pre-commercial-scale floating wind project to be commissioned by 2025 at the latest. The UK is already providing revenue support for the operational 30MW Hywind Scotland project and the up to 50MW Kincardine project is due to be fully operational in 2019. In France, there are 96MW (4 x 24MW) of pilot projects due to be operational by 2020. Between them, these projects will demonstrate the viability of a two different floating substructures, fixations and balance of plant.

Short-term Impacts

There is significant UK supply chain potential for the domestic market in fabrication of key components, including substructures, anchors and moorings, as conveyed directly through the industry workshop and supply questionnaires for this study. A key element of unlocking this potential is developing the processes, techniques and facilities to enable serial production and move towards industrialising these parts of the industry. This is only possible if future pre-commercial projects are larger than what has gone before (30 – 50MW). In addition, economies of scale will make a single 100MW project less expensive to support than, for example, 2 x 50MW projects. 100MW represents a manageable step from small-scale demonstration and one-off oil & gas projects and UK companies will be in a better position to manage this gradual scaling up for the domestic market. UK companies will also have the earliest opportunity to demonstrate capabilities at a larger scale than previously possible and enhance credentials for the export market.

Long-term impacts

The greatest long-term impact of this directional support will be on UK content and exports. Depending on timing (which will dictate the turbine size available), a 100MW project would require ~10 turbines and floating substructures, an order size which would unlock a limited amount of supply chain investment even without a further pipeline. Gaining a strong foothold in the early stages of the domestic and export markets gives a strong base for increasing or at least maintaining market share provided domestic deployment is maintained.

Cost of Support

Based on 100MW with estimated strike price of £150/MWh and the assumed wholesale power price profile, 15-year support would cost £668m (an average of £45m per year).

Risks and Mitigations

Cost of support: With any new technology, which brings innovation and the opportunity for commercialisation of that product there is a risk of cost increase. With any new technology, which brings innovation and the opportunity for commercialisation of that product, there is risk of cost increase. From a public policy perspective, this can be managed by setting a price cap per MWh which is agreed up-front with the project developer and is set for the duration of the support period. The risk of project and operating cost increases is then borne by the project developer/owner. An agreed price cap is more appropriate at this early stage, rather than pricing through a competitive auction as competitive bidding would drive cheap rather than good. The UK needs to be the 'good' or best suppliers to ensure the successful bidding on UK and ROW tender opportunities. Driving down costs too early drives out the ability of our supply chain to compete.

Securing UK content: While a gradual scaling up in project size will provide the best opportunity for the supply chain to prepare for commercial-scale deployment, this does not in itself guarantee high levels of UK content in a 100MW project. UK content in both the domestic and export markets can be further improved through targeted supply chain support, as outlined in the following option.

6.3.2 Public co-investment in key supply chain areas

A significant driver of realising UK supply chain full potential is visibility of future work. Without confidence in the future market, the required investments in facilities, skills and innovation will not happen. Where sufficient confidence in the future pipeline cannot be provided, public co-investment in key segments will reduce the private investment risk; having a public-sector stake in the business can itself inspire confidence in the future of the market.

Short-term impacts

This type of support should be targeted at port facilities and substructure fabrication, where the private sector is not willing to take the risk of the full significant investment. The availability of appropriate port facilities and infrastructure is seen as key to driving high levels of UK content throughout the value chain in the domestic market. While this is not expected to translate directly into exports for these segments (ports services and heavy substructures by their nature are not seen as significant export opportunities), basing these activities in the UK gives more logic for other goods and services to be based in the UK, which in turn will underpin UK companies' export capabilities.

Long-term Impacts

The immediate impact is expected to endure as early supply chain investment and support gives the UK a strong position in domestic and export supply to build on for the longer-term.

Cost of Support

Based on supply chain input, the total investment required in ports and fabrication facilities to service the domestic market is £700m. The public cost of investment will depend on further discussions on specific investments. For modelling, a cost of £350m (50% share) has been included.

Funding is expected to come from a combination of new and existing sources, such as City Deals[20], European Regional Development Funding (ERDF) and Local Enterprise Partnerships (LEP's).

There is already work underway between the public and private sectors to identify and develop appropriate sites for decommissioning of floating oil & gas structures. By acting now, there is an opportunity to identify common requirements and build these into evolving plans – this will allow floating

[20] https://www.gov.uk/government/collections/city-deals

wind needs to be designed in at lower incremental cost than if having to consider two separate sets of upgrades.

Risks

Maintaining supply chain competitiveness: If the public funding effectively becomes a subsidy, there is reduced incentive for continuous improvement and for the company to become and remain quality and cost-competitive. Public co-investment should be genuine so that the money invested earns a return on the same basis as private investment.

Securing UK content: Developing facilities does not guarantee winning contracts. Facilities upgrades should be planned and delivered in close conjunction with technology designers and project developers to ensure the best fit with project and contract requirements.

6.3.3 Enhanced revenue support for first UK commercial-scale projects (up to 800MW)

This option would see a ring-fenced CfD (or similar mechanism) made available at an enhanced rate for the first commercial-scale floating wind projects to be commissioned by at least 2027 (assuming lease available by 2020).

Short-term Impacts

Providing enhanced revenue support for the first UK commercial-scale projects will maintain the UK's lead in floating wind deployment and, most importantly, enable the gradual build out of the UK supply chain. An initial 300MW project would be in line with the lower end of project developer expectations for first commercial projects, being large enough to unlock sufficient economies of scale to achieve the benchmark LCOE of £85/MWh. A commercial-scale project provides an immediate driver for UK companies to develop required solutions, both individually and in collaboration. Further developing this expertise will give a basis for gaining a share of the early export market and a foundation for further developing global market share.

Long-term Impacts

Funding the first 300MW project also creates an option to fund a second early commercial project (~500MW), which would maintain the momentum and provide a smooth pathway to a longer-term pipeline of commercial floating wind projects from 2031 onwards. This will be critical to growing the UK supply chain share of the domestic and export markets to maximum potential. However, a valuable share of both markets should be attainable even just through funding the first commercial project as this keeps the UK engaged and relevant in floating wind.

Cost of Support

Based on 300MW with estimated strike price of £93/MWh and the assumed wholesale power price profile, 15-year support would cost £830m (an average of £55m per year).

Based on 500MW with estimated strike price of £67/MWh and the assumed wholesale power price profile, 15-year support would cost £375m (an average of £25m per year).

The combined cost of support for 800MW is therefore estimated as £1,205m over 15 years.

Risks and Mitigations

Cost of support: The increase in the required CfD level would not align to wider UK policy on reducing overall cost of energy to the consumer; however, investment is required for future opportunities and innovation in order to maintain growth of clean energy options out to 2050. From a public policy perspective, CfD's are managed through an auction or similar process, which means that even at a higher innovation level there is competition to get best value.

Securing UK content: For a number of segments of the UK supply chain (particularly substructure fabrication, moorings, anchors and dynamic cables), moving straight to commercial-scale projects would represent a significant step from supplying demonstration-size floating projects or the one-off nature of oil & gas projects. The supply chain benchmarking indicates that there is concern over UK companies' ability to deliver to the volumes and timescales necessary for commercial-scale projects. Based on supply chain survey responses, a 300MW project would require investments in the region of £30m in fabrication and £25m in port facilities. The order value of ~£200m for substructure fabrication, even as a one-off, would justify a portion of the investment, provided there is sufficient lead-time to implement upgrades in time for fabrication and delivery. However, the one-off use of port facilities is not likely to justify the estimated £25m investment and, without visibility of a future floating wind pipeline, would require public investment. With access to suitable UK ports underpinning a significant part of the UK supply chain opportunity for the domestic market, there is therefore a risk that early commercial UK projects will use a lower % of UK content.

This risk can be mitigated through implementing appropriate supply chain support measures and more of a staged approach to deployment volumes as outlined in Sections 6.3.1 and 6.3.2.

6.4 Policy Conclusions

Each form of support analysed is a single option, or combined set of options to enable the UK economic value from a floating wind sector.

Seabed rights are or will be throughout 2019, accessible at both pre-commercial and early commercial scale through The Crown Estate and Crown Estate Scotland.

ORE Catapult believes that providing revenue support for one or more pre-commercial projects and co-investing with key elements of the supply chain puts the UK in the best position to realise value from the early and ongoing stages of floating wind deployment both from the domestic and export markets.

As well as creating capability and maximising long-term value, each stage of support will also directly generate GVA and jobs from the projects supported. The cost and GVA for each stage of support both individually and cumulatively under three potential policy scenarios described and assessed in Section 7 on Scenario Analysis.

7 Scenario Analysis – The Value to the UK of Floating Wind

7.1 Scenarios Overview

Three scenarios have been analysed based on following different combinations of the above policy options. The scenarios chosen highlight the impact of a gradual scaling-up in project size and supply chain capability and, based on industry input, would give the most UK economic value.

Support for further pre-commercial projects was felt to be most valuable when accompanied by supply chain co-investment, otherwise there is increased risk of having a UK-funded project which uses low levels of UK content and does not provide the required supply chain development opportunities.

Maximum long-term economic benefit is expected to be created from implementing all of the above measures of support. This makes up Scenario 1.

Scenario 2 considers that there are two demonstration projects in the UK already and that there is a decision to only support early commercial projects in the future.

If no support is provided for the early stages of UK floating wind deployment, the minimal amount of value will be created and this is demonstrated in Scenario 3.

For each scenario, the impact on UK deployment and UK content in the domestic and export markets is assessed within the deployment and UK content ranges detailed in sections 4 and 5 of this report. In each case, ROW deployment is held constant at 2GW per year from 2031 to 2050. The key inputs for the four scenarios are summarised in Table 6.

No.	Scenario Name	UK Supply Chain Support	Pre-commercial MW supported	Early commercial MW supported	Annual UK commercial deployment from 2031	Annual ROW deployment from 2031	UK content Domestic (lifetime)	UK content Exports (lifetime)
1	Pre-commercial and Supply Chain Support Plus Early Commercial Support	Yes	100MW	800MW	1,000MW	2,000MW	65%	10%
2	Early Commercial Support Only	No	-	800MW	750MW	2,000MW	49%	6%
3	Current Policies	No	-	-	500MW	2,000MW	22%	3%

Table 6: Scenario Inputs Summary

The full breakdowns of estimated UK content for the domestic and export markets in 2031 and 2050 are shown in Appendix 5. The highest UK content for both the domestic and export markets is achieved under Scenario 1, where strong, early support is provided. Crucially, this includes the benefit of developing UK ports and fabrication facilities to capture a high portion of the available domestic market, and increased UK deployment, making supply chain investment in the UK more attractive for overseas companies. The 65% (domestic market) and 10% (export market) lifetime market shares by 2050 are consistent with our expectations for UK offshore wind overall.

Scenario 2, where early commercial projects are supported, but without gradual scale-up and supply chain support, allows the UK to eventually achieve similar levels of UK content in domestic and export markets to those currently being achieved in bottom-fixed offshore wind. However, the lack of co-investment in key port and fabrication facilities and staged project and supply chain scale-up means that these shares are lower than for Scenario 1 and will take longer to achieve as the UK must claw back market share.

The lowest UK content for both the domestic and export markets occurs under Scenario 3, where no support is provided. The 22% and 3% lifetime market shares by 2050 are driven by the supply chains in other countries gaining first mover advantage in export markets and being able to provide services into the UK market more competitively than UK suppliers.

A summary comparison with existing ORE Catapult current and future estimates of UK content in the UK domestic and export markets for bottom-fixed offshore wind is shown in Table 7.

Element	Actual Reported 2016	ORE Catapult Offshore Wind 2030	ORE Catapult Offshore Wind 2050	Floating Max. Estimate 2050	Floating Min. Estimate 2050
Capex	29%	40%	52%	50%	13%
Opex	75%	79%	84%	85%	38%
Devex	73%	73%	74%	80%	39%
Total	**48%**	**57%**	**65%**	**65%**	**22%**

Table 7: Comparison of UK Content Estimates

7.2 Scenario 1 – Early Commercial Support Plus Pre-commercial and Supply Chain Support

7.2.1 Scenario 1 Analysis

The UK makes leases available and provides revenue support for 100MW of pre-commercial projects by 2025 (at the latest) to provide gradual progression towards commercial-scale projects beginning in 2027 (at the latest). The public sector co-invests up to £350m (matched by private sector) in key port and steel fabrication facilities. This allows the UK supply chain to achieve its maximum estimated potential of 65% of project lifetime value in the domestic market and 10% of the global export market by 2050.

Revenue support is also made available at an enhanced rate (reducing over time) for early commercial-scale projects. A first commercial-scale project of 300MW is installed in 2027 and a second of 500MW in 2029.

The global export market volume is 1GW per year from 2027 – 2030 and 2GW per year from 2031. With enhanced supply chain capability, the UK is able to install an average of 1GW per year of commercial-scale floating wind from 2031 to 2050, reaching 20GW of mature commercial projects and pushing industry achievements towards the upper end of ambition of 70GW of UK offshore wind by 2050.

The UK supply chain achieves 65% of the lifetime content of UK projects and 10% for the global export market by 2050.

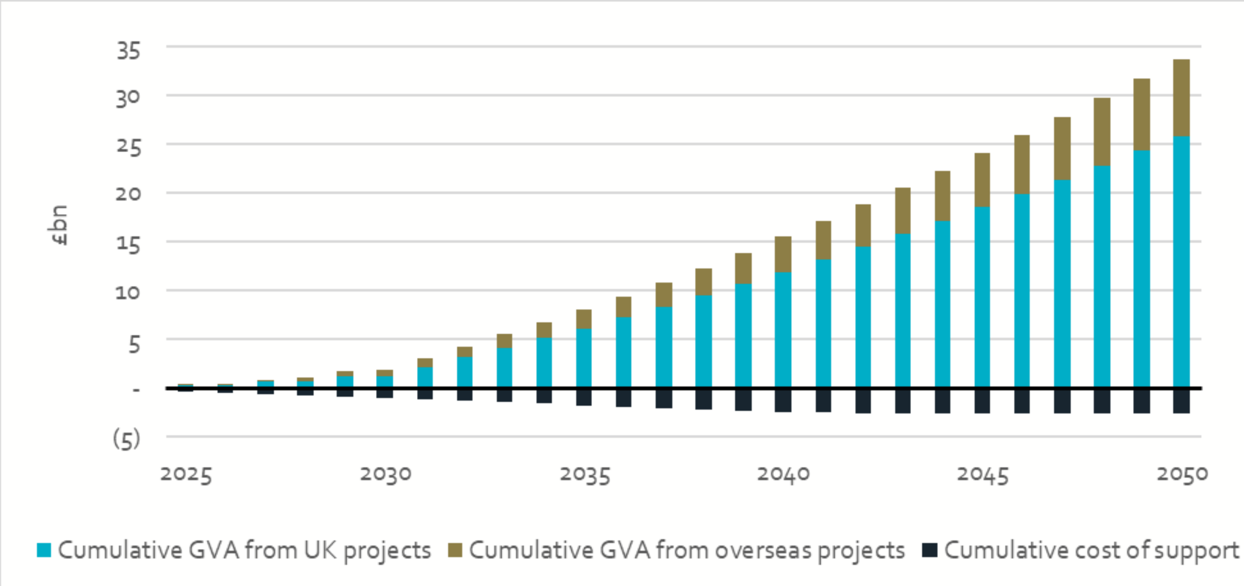


Figure 15: Scenario 1 - Cumulative GVA vs Cost of Support

Modelling results show cumulative GVA of £33.6bn by 2050 compared to a cost of support of £2.2bn. As shown in Figure 15, the cost of support will be paid back between 2030 and 2031 with GVA being created rapidly with a high UK share of the domestic market and a significant contribution from exports to a growing global market. This represents a very high ratio of GVA supported to cost of support of 15:1.

Similarly, the number of jobs supported ramps up quickly to reach 11,000 by 2031 and 17,000 by 2050, comprising 9,300 direct and 7,700 indirect jobs, as shown in Figure 16.

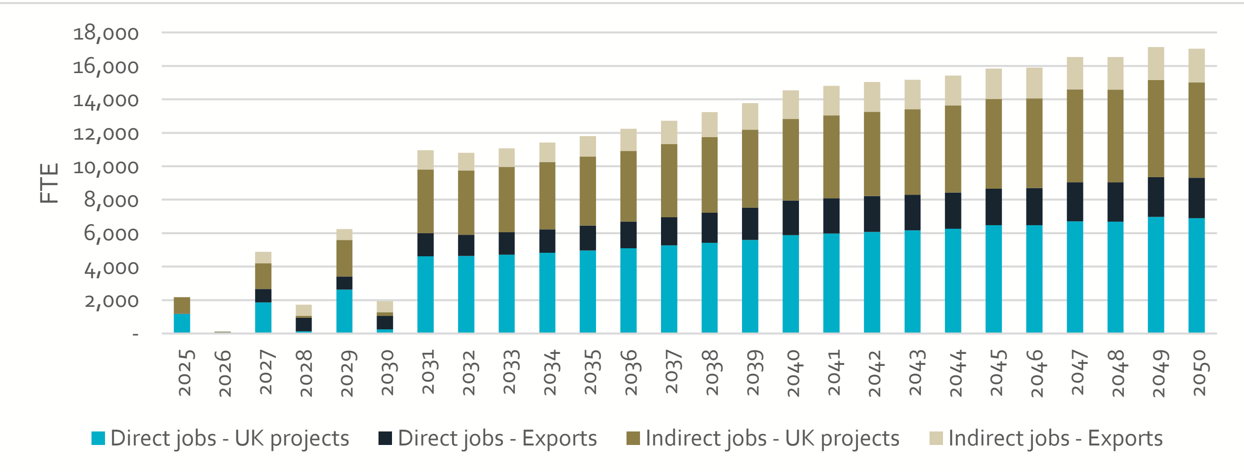


Figure 16: Scenario 2 – Jobs supported

7.2.2 Scenario 1 Sensitivity Analysis

Scenario 1 represents a very high return on investment and it is important to understand the impact if the market or UK supply chain do not develop as expected.

Downside Sensitivity

In a case where UK and global deployment are halved, to 500MW and 1GW per year respectively, cumulative GVA by 2050 would be reduced from £33.6bn to £20bn and jobs supported reduced from 17,000 to 9,900. This would still represent a GVA to cost ratio of 9:1.

If the reduced deployment had a knock-on impact on UK content, reducing UK supply chain share of domestic and export markets by 50%, GVA and jobs supported would be further reduced to £11bn and 5,000. This would still represent a GVA to cost ratio of 5:1 and net value creation of £8.8bn (£11bn GVA - £2.2bn cost of support).

Upside Sensitivity

In a case where our maximum estimated potential of 95GW floating wind in ROW and 20GW in the UK are deployed by 2050, the industry could support up to £39bn in GVA and 20,000 jobs, assuming that UK companies could maintain the same share of the domestic and export markets. With this increased deployment, even a reduced market share could allow the UK supply chain to capture more value in absolute terms.

7.2.3 Scenario 1 Conclusions

The cost of pursuing the set of policies under Scenario 1 is estimated at £2.2bn, which is a significant cost. However, this can be considered a very attractive investment with a potential return of 15x the amount invested. In a highly pessimistic sensitivity where market size and UK market share are reduced by 50%, a return on investment of 5x can still be achieved. This shows that the potential gain far outweighs the potential risks.

7.3 Scenario 2 – Early Commercial Support Only

7.3.1 Scenario 2 Analysis

The UK makes leases available and provides revenue support at an enhanced rate (reducing over time) for early commercial-scale projects. A first commercial-scale project of 300MW is installed in 2027 and a second of 500MW in 2029.

The global export market volume is 1GW per year from 2027 – 2030 and 2GW per year from 2031. With good supply chain capability but no structured pathway to scaling up from demonstration-size (~30MW) projects, the UK is able to install an average of 750MW per year of commercial-scale floating wind from 2031 to 2050, reaching 15GW of mature commercial projects and pushing industry achievements above minimum expectations of 50GW of UK offshore wind by 2050.

The UK supply chain is able to achieve 49% of the lifetime content of UK projects and 6% for the global export market.

Modelling results show cumulative GVA of £18.1bn by 2050 compared to a cost of support of £1.2bn. As shown in Figure 17, the cost of support will again be paid back between 2030 and 2031 with GVA being created rapidly with a medium UK share of the domestic market and a significant contribution from exports to a growing global market. As with Scenario 1, this represents a very high ratio of GVA supported to cost of support of 15:1.

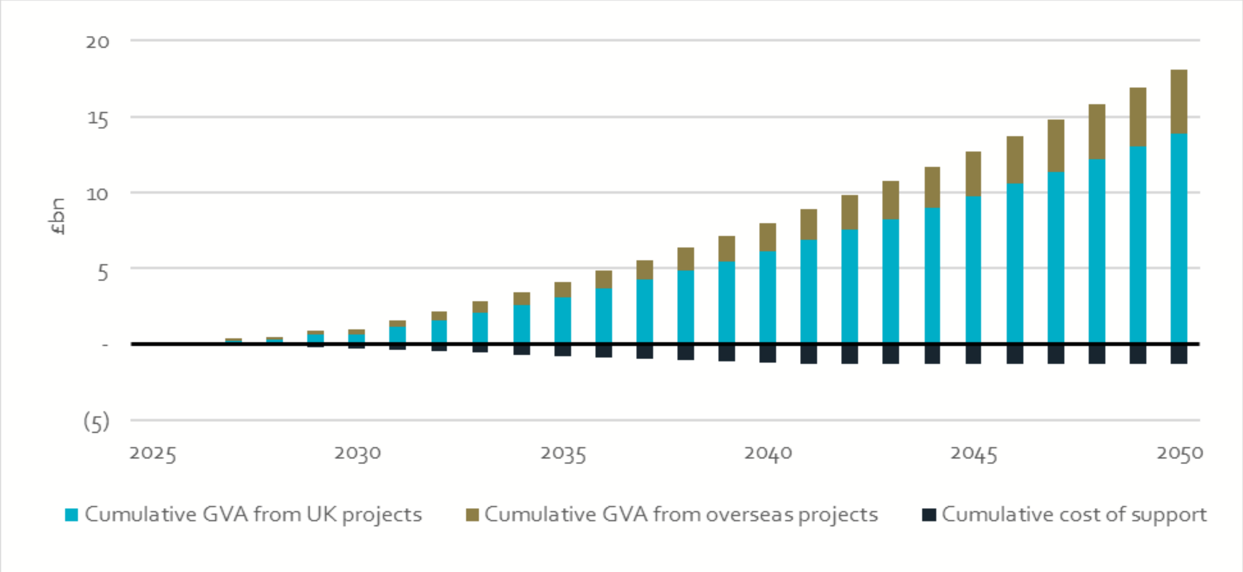


Figure 17: Scenario 2 - Cumulative GVA vs Cost of Support

Similarly, the number of jobs supported ramps up quickly to reach 5,400 by 2031 and 9,700 by 2050, comprising 5,300 direct and 4,400 indirect jobs, as shown in Figure 18.

Figure 18: Scenario 2 – Jobs supported

7.3.2 Scenario 2 Sensitivity Analysis

Scenario 2 represents a very high return on investment and it is important to understand the impact if the market or UK supply chain do not develop as expected.

Downside Sensitivity

In a case where UK deployment is reduced to 500MW per year and global deployment halved to 1GW per year, cumulative GVA by 2050 would be reduced from £18.1bn to £13bn and jobs supported reduced from 9,700 to 7,000. This would still represent a GVA to cost ratio of 12:1.

If the reduced deployment had a knock-on impact on UK content, reducing UK supply chain share of domestic and export markets by 50%, GVA and jobs supported would be further reduced to £8bn and 4,100. This would still represent a GVA to cost ratio of 7:1.

Upside Sensitivity

In a case where our maximum estimated potential of 95GW floating wind in ROW and 20GW in the UK are deployed by 2050, the industry could support up to £23bn in GVA and 13,000 jobs, assuming that UK companies could maintain the same share of the domestic and export markets. With this increased deployment, even a reduced market share could allow the UK supply chain to capture more value in absolute terms.

7.3.3 Scenario 2 Conclusions

The cost of pursuing the set of policies under Scenario 2 is estimated at £1.2bn, which is a significant cost. However, this can be considered a very attractive investment with a potential return of 15x the amount invested. In a highly pessimistic sensitivity where market size is reduced to our lowest estimate and UK market share are reduced by 50%, a return on investment of 7x can still be achieved. This shows that the potential gain far outweighs the potential risks.

It is also worth noting that supporting the first 300MW commercial-scale UK project can be seen as providing the option to support further floating wind projects before global deployment and learning has reduced costs sufficiently for floating wind to compete on cost with other offshore wind projects. Exercising this option is expected to incur a total cost of £1.2bn and result in the £18.1bn of GVA and 9,700 jobs detailed, above. If the option is not exercised, and the UK does not deploy further floating wind beyond the first 300MW until it is cost-competitive, this will still provide a foundation for UK companies to demonstrate capability and access the global market at the same time as competitors. As illustrated, above, the risk of creating this option appears to be far lower than the risk of not creating it.

7.4 Scenario 3 – No Support for Early Stage UK Floating Wind Deployment

7.4.1 Scenario 3 Analysis

The UK makes leases available for commercial-scale projects, but with no enhanced revenue support for early commercial-scale projects. No further floating wind projects are installed in the UK until floating wind is able to compete on cost (estimated as 2031).

The global export market volume is 1GW per year from 2027 – 2030 and 2GW per year from 2031. With supply chain capability under-developed and no structured pathway to scaling up from demonstration-size (~30MW) projects, the UK only installs an average of 500MW per year of commercial-scale floating wind from 2031 to 2050, reaching 10GW of mature commercial projects and contributing to industry achievements at minimum expectations of 50GWof UK offshore wind by 2050.

The UK supply chain is able to achieve 22% of the lifetime content of UK projects and 3% for the global export market.

Figure 19: Scenario 3 - Cumulative GVA vs Cost of Support

Modelling results show cumulative GVA of £6.8bn by 2050 but at no cost in public support. As shown in Figure 19, GVA is created steadily, but with a low UK share of the domestic and export markets.

Similarly, the number of jobs supported ramps up steadily but only reaches 2,600 by 2031 and 3,600 by 2050, comprising 2,000 direct and 1,600 indirect jobs, as shown in Figure 20.

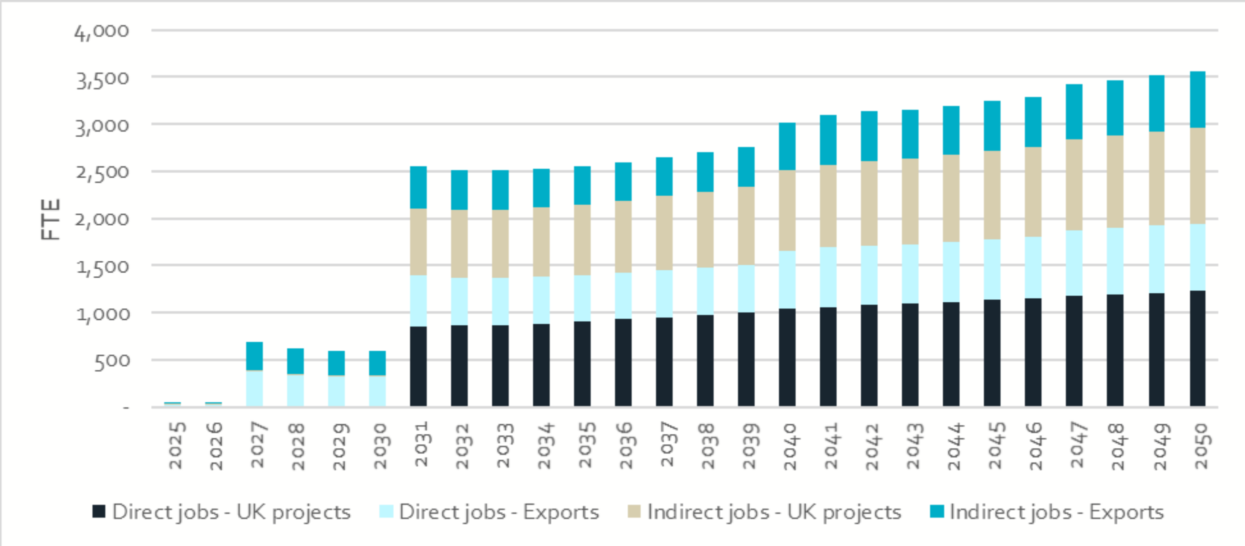


Figure 20: Scenario 3 – Jobs supported

7.4.2 Scenario 3 Conclusions

There is no cost directly attached to Scenario 3, where floating wind is only deployed in the UK once cost-competitive. This is the cheapest option, but will also realise the lowest amount of value, supporting only 20% of the potential GVA and jobs which can be realised under a supportive policy environment.

7.5 Scenario Conclusions

Provided the UK begins to deploy floating wind before costs have reduced sufficiently to be subsidy-free, there will be an associated cost to enable the supply chain and additional economic value. The maximum possible economic benefits can be achieved through support into further pre-commercial projects and investment into the UK supply chain as in Scenario 1. In Scenario 2, where the UK supports first commercial-scale projects without providing a structured path for the UK supply chain to scale up, significant, but reduced, value can still be created. See Figure 24 which provides a summary of all the scenarios and possible benefits from each.

If the UK should wait to deploy floating wind at commercial-scale until floating wind is cost-competitive with bottom-fixed offshore wind and other forms of renewables, the cost in terms of revenue support can be eliminated. However, as in Scenario 3, this comes at the cost of supporting 13,400 fewer jobs and £26.8bn less GVA by 2050 than could be achieved by playing a leading role in developing the industry and the UK supply chain.

The £6.8bn GVA and 3,600 jobs realised from not providing policy support for the early stages of UK floating wind deployment is lower than the net value realised of £8.5bn and 5,000 with full policy support, even in the most pessimistic scenario.

Summary comparisons of costs and benefits under each scenario are shown in Figure 21 to Figure 23.

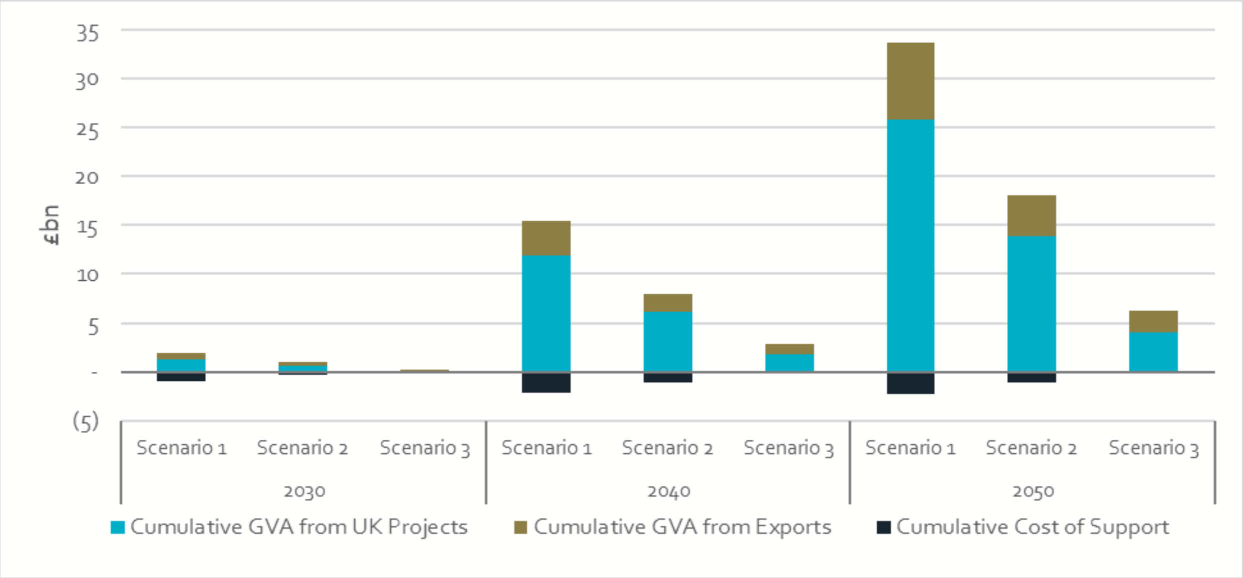


Figure 21: Cumulative GVA scenario comparison

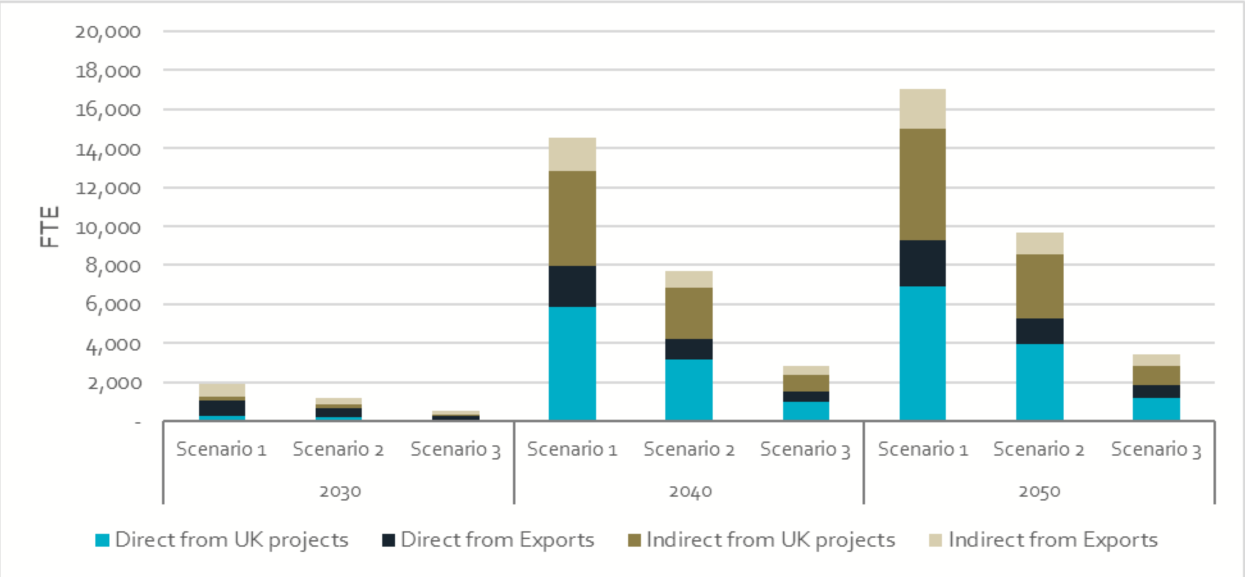


Figure 22: Annual jobs supported scenario comparison

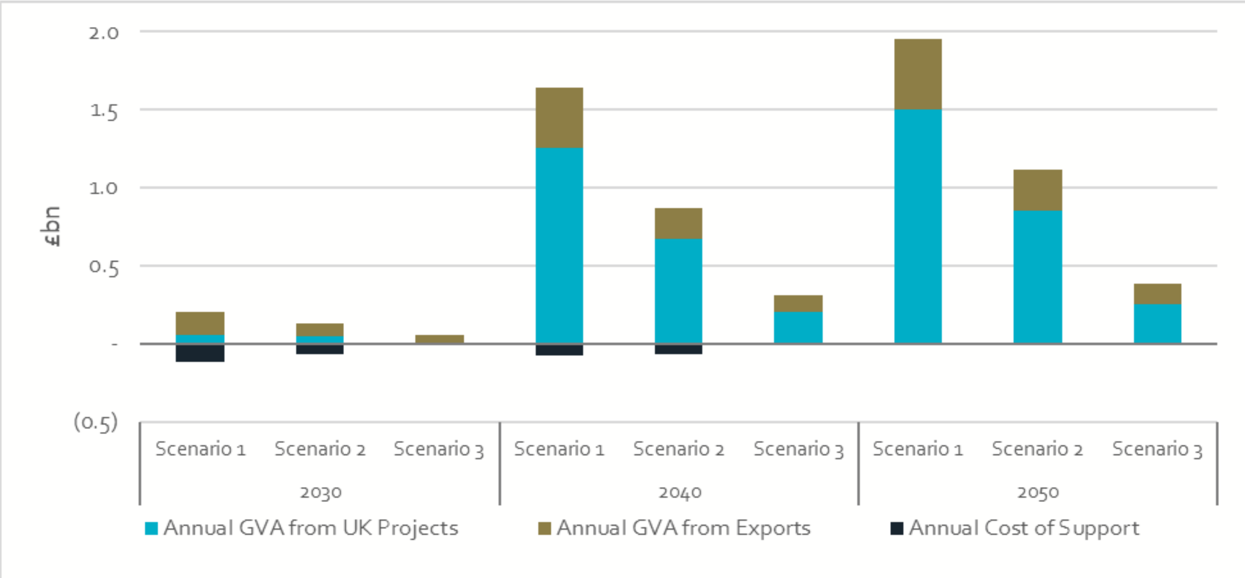


Figure 23: Annual GVA scenario comparison

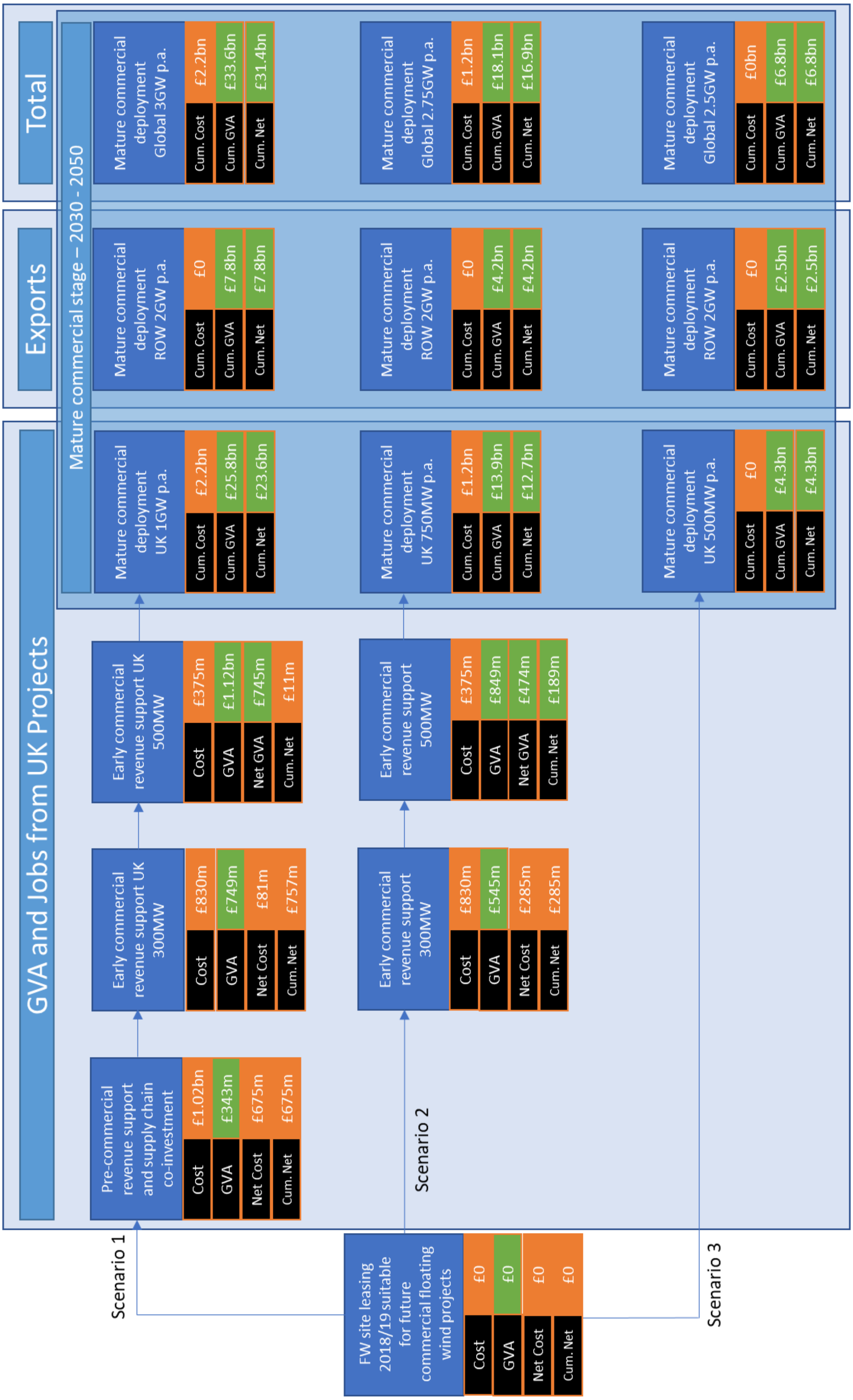


Figure 24: GVA and cost implications of each Scenario

8 Conclusions

8.1 Floating Wind Opportunity

The development of the floating wind industry represents a valuable economic opportunity for the UK. The abundance of potential resource in UK waters and the natural fit with existing UK supply capabilities mean that it will play a key part in enabling the UK industry to realise its ambitions of at least 50GW by 2050, driving the industry towards the upper end of ambition and unlocking the full potential of GVA and jobs targeted.

8.2 Public and Private Investment Required

Sustained commercial-scale deployment of floating wind will only be realised if sufficient cost reduction can be achieved. Key drivers of the required cost reduction will be serial fabrication of substructures, standardisation of components and processes and development of port facilities with the required specifications. This requires a number of private industry and public policy actions to be taken up-front as documented in Sections 5 and 6 of this report, including direct revenue support to floating wind projects and investment in key infrastructure assets. The maximum cumulative investment in revenue and supply chain support by 2050 is estimated at £2.2bn.

8.3 Return on Investment

In return for this investment, the floating wind industry could be worth a net economic benefit of £2bn per year by 2050. The return for this investment would be 9,300 direct and 7,700 indirect jobs and £33.6bn of GVA supported by 2050, representing £15 of GVA for each £1 invested in early stage support. Economic benefits will accrue from the supply chain winning a large share of the domestic and export market and from allowing a smooth transition for personnel and organisations from a retreating oil & gas sector.

8.4 Risks and Sensitivities

Providing policy support for the early stages of UK floating wind deployment carries a risk that the global market will not evolve to the extent expected and that UK companies will not capture the share of domestic and export markets anticipated. Sensitivity analysis demonstrates that even in highly pessimistic scenarios where deployment and UK market share are reduced by 50%, the investment through revenue and supply chain support will realise a return of 5 - 7 x the amount invested. In such a pessimistic scenario, the net value created from providing full policy support would still be higher than the value created through not providing policy support for the early stages of UK floating wind deployment.

Appendix 1 - GVA and Jobs Creation Methodology

Background

Directly relevant studies applying similar methodologies include:

[1] Beatrice Offshore Windfarm Limited project Socio-economic impact report, July 2017, SSE

http://sse.com/media/475202/Beatrice-Socio-economic-impact-report-v2_BMF_FINAL_200717.pdf

[2] Calculating the economic contribution of Beatrice Offshore Windfarm Limited, SSE (Methodology Document accompanying ref [1])

http://sse.com/media/475205/BOWL-methodology-document-FINAL.pdf

[3] Economic Impact Study into the Development of the UK Offshore Renewable Energy Industry to 2020

https://ore.catapult.org.uk/wp-content/uploads/2016/05/Economic-Impact-Study-into-the-Development-of-the-UK-Offshore-Renewable-Energy-Industry-to-2020.pdf

[4] The Future's Floating – Friends of Floating Wind, January 2018

http://www.atkinsglobal.com/~/media/Files/A/Atkins-Corporate/group/sectors-documents/renewables/library-docs/brochures/Friends-of-floating-the-futures-floating-FINAL.pdf

Data Sources

[5] ONS Input-Output Analytical Tables 2013

https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/ukinputoutputanalyticaltablesdetailed

[6] ONS Annual Survey of Hours and Earnings (ASHE) 2017 (provisional)

https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/earningsandworkinghours/datasets/industry2digitsicashetable4

[7] Scottish Government Input-Output Analytical Tables 2014

http://www.gov.scot/Topics/Statistics/Browse/Economy/Input-Output/Downloads/IO1998-2014Latest

GVA Definition

Gross value added (GVA) measures the total economic income produced in an economy in a period of time. GVA provides a monetary value for the amount of goods and services that have been produced, less the cost of all inputs and raw materials that are directly attributable to that production. It is also referred to as the sum of capital and labour income.

Direct GVA – The construction and operation of offshore wind farms generates demand for relevant products and services. Production and supply of these products and services leads to creation of capital and labour income within the directly affected industry sectors. This results in a GVA/Turnover ratio for each industry sector.

Indirect GVA – Production and supply of these products and services in the industry sectors directly leads to consumption of goods and services produced by other industry sectors, thereby leading indirectly to creation of capital and labour income within these indirectly affected industry sectors. This results in a Type I GVA multiplier, which summarises the impact on aggregate GVA of a unit increase in GVA in one sector: Type I Multiplier = (Direct + Indirect GVA) / Direct GVA

Induced GVA - As wages and salaries (labour income) increase in line with increased output of industries, there may also be an induced effect leading to increased demand by households for goods and services. This results in a Type II multiplier: Type II Multiplier = (Direct + Indirect + Induced GVA) / Direct GVA.

GVA Estimation

Note that the methodology refers to both Product codes and SIC codes. Currently only Product x Product Tables are available and so are the basis for our analysis. The most recent complete set of UK Input-Output data is for 2013.

Judgement required – Estimate the % of UK content in expected spend for each major cost centre then map major cost centres to ONS Product codes (or Standard Industrial Classification (SIC) codes).

Estimate Direct GVA – Use Office for National Statistics (ONS) published Input/Output tables to obtain GVA/Turnover ratio for each major cost centre based on mapping. Apply GVA/Turnover ratio to expected spend in order to estimate GVA by cost centre.

Estimate Indirect GVA – Apply ONS published Type I multipliers for relevant ONS Product codes (or SIC codes) to Direct GVA estimates in order to estimate Indirect GVA.

Estimate Induced GVA – Use ONS published Input/Output tables to derive Type II multipliers by linking changes in household income to changes in industry sector output. Apply the derived Type II multipliers for relevant ONS Product codes (or SIC codes) to Direct GVA estimates in order to estimate Induced GVA.

Jobs Creation Estimation

Judgement required – Map major cost centres to Industry categories in ONS Annual Survey of Hours and Earnings (ASHE) 2017 (provisional) to estimate average gross labour cost per employee for each major cost centre.

Estimate Direct Jobs – Divide total labour spend (estimated in Direct GVA calculation) in each major cost centre by relevant average annual gross labour costs per employee to give estimate of direct jobs.

Estimate Indirect Jobs – Apply ONS published Employment multipliers for the relevant ONS Product codes (or SIC codes) to estimate number of indirect jobs.

Cost Centre Mapping

The major floating wind cost centres have been mapped to product codes as shown in Table 8.

Activities	SIC Code	Description
Development Services (PM, Development and Consenting, Surveys, Certification)	74	Other professional, scientific and technical services
Substructure (steel or concrete including substation)	24	Basic iron and steel
Wind turbine	24	Basic iron and steel
Anchors	24	Basic iron and steel
Mooring lines	24	Basic iron and steel
Electrical infrastructure (array and export cables, top-side of substation)	27	Electrical equipment
Ports & Logistics	43	Construction
Cranes	43	Construction
Vessels and subsea engineering	33	Rest of repair; Installation - 33.11-14/17/19/20
	50	Water transport services
Major & minor repairs	33	Rest of repair; Installation - 33.11-14/17/19/20
	50	Water transport services
Decommissioning	43	Construction
	50	Water transport services
Insurance	65	Insurance and reinsurance, except compulsory social security & Pension funding
Regulatory charges/Other Opex	82	Office administrative, office support and other business support services

Table 8: Floating Wind Cost Centre Mapping to Product Codes

Appendix 2 - Stakeholder Engagement

Supply Chain Segment	Stakeholder
Design	DNV Quoceant Tension Technology International Wood
Manufacture	Babcock BAM Nuttall Bridon International Ltd Bruce Anchor CSWind Fergusons Ship Yard - Clyde Blowers Global Energy Group Offspring International
Ports / Assembly	Milford Haven Port Authority Kishorn Port & Drydock Peel Ports (Hunterston)
Installation / O&M	Fugro Petrofac Siem Offshore Contractors Subsea7

Supply Chain Segment	Stakeholder
Owner/Operator	Atlantis Resources EDF Innogy Macaskill Associates Statoil
Technology developer	Floating Power Plant Hexicon IDEOL Principle Power SBM Offshore Statoil
Other	Carbon Trust Oil & Gas Technology Centre Scotia Supply Chain Ltd

Appendix 3 – Floating Wind Substructures Overview

 Credit: IDEOL	Typology: barge Primary material: concrete Unique features: synthetic moorings The first offshore wind turbine in France 2018 Full-scale to be installed in France
 Credit: PrinciplePower Inc	Typology: semi-submersible Primary material: steel Unique features: trim system The only design to be decommissioned 2011 Full-scale prototype installed in Portugal

 Credit: Statoil	Typology: spar Primary material: steel Unique features: control system 2009 First full-scale floating offshore wind turbine installed in Norway 2017 First floating offshore wind farm installed in Scotland
 Credit: GICON	Typology: TLP Primary material: Steel + concrete Unique features: self-installing 2016 should have seen a prototype installed (permitting issues)

Appendix 4 – Supply Chain Detailed Analysis

1. Development Services (Development and Consenting, Surveys, Certification, PM)

% Lifetime Cost (Undiscounted)	Unique to FW (Y/N)	UK expertise (Y/N)	Domestic Share (High/ Medium/ Low)	Export potential (High/ Medium/ Low)	Commercial readiness (Y/N)
4%	N	Y	High	Medium	Y

Scope of Services

Wind and wave analysis, seabed and environmental surveys, certification, consenting, project management and finance.

Unique to Floating Wind

Floating wind-specific consenting requirements are yet to be defined, meaning that the exact scopes of work for consultancies will evolve. Also, for wind and wave assessments, it is expected that floating buoy LiDARs will be needed as deep waters prohibit the use of bottom-fixed met masts. However, in general, these services show many similarities to bottom-fixed offshore wind and the oil & gas sector.

Existing UK Expertise

A number of specialist UK companies are already active in the offshore wind and oil & gas industries, providing a solid base for servicing UK projects. Project developers often prefer in-house resources, especially in project management, but outsourcing is used wherever specialist advice is needed. UK companies have an established knowledge of the local environmental conditions and UK regulations which increases their attractiveness to developers of UK floating wind projects.

Domestic Market Share

UK Development services companies are expected to win a high share of UK projects, based on the logic for local supply and success to date in offshore wind.

Export Potential

Export potential is assessed as medium. There is a strong logic for local supply rather than importing from overseas. However, the UK is in a unique position as the only potentially leading floating wind market with experience of consenting and building large scale offshore wind projects – there is a very limited track record in the emerging markets (Japan, France, USA, Taiwan, Norway). This can provide UK companies with an advantage in gaining access to providing development and project management services for early projects and with potential to secure future market share based on early success.

Commercial Readiness

In general, development services require no special adjustments to support commercial projects in the UK. Internal investment in the order of millions of pounds will be required by companies wishing to capitalise on the export opportunities.

Key Companies with UK Presence

Aarufield, Adus Deep Ocean, APEM, Apollo Offshore Engineering, Aquatera, Atkins, Augmentias, Babcock International Group, Bibby Offshore, Briggs Marine, Cyberhawk Innovations, ESS Ecology, Fugro Renewables, Global Energy Group, Hydrosphere, LR Senergy, MacArthur Green, Maritime Craft Services, Met Office, Mott MacDonald, Natural Power Consultants Ltd, Oldbaum Services Ltd, Partrac Ltd, TTI Marine Renewables, Wessex Archeology, Wood Group Kenny, Xodus Group

2. Substructures

% Lifetime Cost (Undiscounted)	Unique to FW (Y/N)	UK expertise (Y/N)	Domestic Share (High/ Medium/ Low)	Export potential (High/ Medium/ Low)	Commercial readiness (Y/N)
12%	N	Y	Medium	Low	N

Scope of Services

Design and manufacture of steel or concrete substructures for turbines and for offshore substations.

Unique to Floating Wind

Floating wind substructures are mostly adapted designs of the offshore oil & gas platforms used widely in the North Sea during the last decades and are much more standardised compared to bottom-fixed foundations so knowledge and expertise from this area is readily transferable. The unique aspect for floating wind, as highlighted in feedback from supply chain companies, is that a different design culture is needed, with a focus on low cost and higher production volumes, compared to oil & Gas.

The key challenge for floating wind substructure manufacture is to move from the one-off nature of oil & gas platforms to facilities, processes and skills which enable serial production of large units.

Existing UK Expertise

Although the current original floating wind designs have been mostly developed by non-UK companies, there is engineering consultancy capability in the UK which can be utilised in the design optimisation. For example, in 2016, Atkins engineering company was hired to provide detailed design for Hexicon's multi-turbine floating offshore wind platform and is being involved in many other floating wind projects.

Welding skills exist in the UK from bottom-fixed offshore wind, oil & gas and shipbuilding, but labour costs are high compared to other countries in Europe and Asia. Steel is often imported from other European countries (Spain, Poland) which offer lower costs. UK fabricators have a good reputation for quality and established track record manufacturing oil & gas platforms. While serial production of substructures for commercial windfarms is not currently possible without investment in upgrading infrastructure, companies such as Global Energy Group (at Nigg), Smulders (Newcastle-Upon-Tyne) and Tata Steel (in Hartlepool and Port Talbot) are investing in plant improvements and moving towards competing with others in serial production. Access to a developing floating wind market will assist these, and other UK companies, with filling order books and justifying further investment.

Cement is less exposed to price fluctuations. UK concrete fabricators are active in the construction, oil & gas and offshore wind industries.

Domestic Market Share

Domestic market share is assessed as medium. There is strong logic for local supply of substructures which are likely to weigh up to 3,000 tonnes (steel) or 15,000 tonnes (concrete) and require a surface area of 80m x 80m for 10MW turbines. UK companies also have a proven track record and strong reputation for quality production. These favourable factors are partly offset by relatively high current UK costs compared to countries such as Poland, Spain and China, even taking into account the transportation premium. However, there is an opportunity for UK companies to become more price competitive through investing in facilities, innovation, processes and skills to enable serial fabrication – no country has yet fully developed these capabilities.

Export Potential

Export potential overall is assessed as low. There is very little logic to the key floating wind markets importing large structures from the UK. Markets in Asia have ready access to highly cost-competitive manufacturing and the export distance from the UK is punitive; the USA is expected to heavily promote local content and the export distance from the UK is punitive; France is expected to heavily promote local content. In addition, if UK companies can capture a significant share of the domestic market, there will be limited capacity to produce for export. However, if the floating wind market develops in Ireland, this will be a real opportunity for UK companies, including Harland & Wolff, which is currently the only viable fabricator on the island of Ireland.

Commercial Readiness

Assuming commercial-scale windfarms in the range of 500MW – 1GW, even one floating project per year would require in the region of 50 – 100 substructures to be produced. One fabricator estimated they could produce up to 10 units per year with current capabilities and facilities. Investment in serial production of up to £20m per site across a number of sites will be critical to enable commercial-scale manufacture. Conveyor belt-type operations can allow multiple unit manufacturing based on simplified designs. Industry respondents also indicated that strong political support will be crucial, including the need to be able to access credit guarantees for export as well as provision of support with working capital in order to manage cash flows for work in progress pending payment from customers.

Key Companies with UK Presence

Babcock, BAM Nuttall, BiFab, Cambrian Engineering Cymru Ltd, Fergusons Ship Yard - Clyde Blowers, Global Energy Group, Hutchinson, Liberty Steel, Skanska UK PLC, Francis Brown Limited, Harland and Wolff Heavy Industries Ltd, Rigmar Marine Group, Tata Steel,

3. Wind Turbine

% Lifetime Cost (Undiscounted)	Unique to FW (Y/N)	UK expertise (Y/N)	Domestic Share (High/ Medium/ Low)	Export potential (High/ Medium/ Low)	Commercial readiness (Y/N)
22%	N	Y	Medium	Low	Y

Scope of Services

Design and manufacture of all turbine parts; blades, hub, drivetrain, nacelle and tower.

Unique to Floating Wind

Blades, drivetrain and tower are similar to the components used in current offshore wind applications. Blades are identical to those for bottom-fixed offshore wind except that blade pitch actuators should be modified. Towers for floating wind turbines need to be stiffer and heavier than in bottom-fixed offshore wind due to the difference in loads, forces and movement applied on floating turbines.

Existing UK Expertise

The UK now has blade manufacturing facilities for two OEM's (Siemens in Hull and MHI Vestas on the Isle of Wight). Larger turbines considered for bottom-fixed and floating wind projects to increase energy output will require drivetrains with heavier gearbox or gearless generators. The UK has drivetrain component suppliers and a strong expertise in this area which is already utilised in offshore wind but currently not for large orders. The UK is home to one tower manufacturer, but upgraded facilities will be required to be able to produce tower sections large enough for wind turbines of 10MW+ and to transport them to the harbour.

Domestic Market Share

Domestic market share is assessed as medium. There has been a conscious drive by OEM's to locate blade production in the UK and by OEM's and developers to focus tower production for UK projects in UK facilities. However, the location of the main OEM nacelle assembly facilities, limited range of components produced in the UK and lack of capability for large orders limit the total value of the UK market which can be captured.

Export Potential

Export potential is assessed as low. Key limiting factors are the same as highlighted for domestic market share.

Commercial Readiness

Components are already being produced for commercial-scale projects. Investment in tower manufacturing facilities will be required to capitalise on the opportunity to capture a large share of the UK market.

Key Companies with UK Presence

CSWind, GE, MHI Vestas, Moventas, Siemens, Wood Group

4. Anchors

% Lifetime Cost (Undiscounted)	Unique to FW (Y/N)	UK expertise (Y/N)	Domestic Share (High/ Medium/ Low)	Export potential (High/ Medium/ Low)	Commercial readiness (Y/N)
1%	N	Y	Medium	Medium	Y

Scope of Services

Design and manufacture of all types of anchor, including drag-embedded, suction, gravity and piled.

Unique to Floating Wind

Anchors already used in oil & gas and shipping applications are suitable for floating wind applications with minor adjustments in design.

Existing UK Expertise

There is existing strong UK capability for anchor supply due to years of experience in supplying anchors for the oil & gas industry. Supply chain companies should focus efforts on the development of robust anchoring systems, improvement of integrated designs (with the wider mooring system) and understanding of geotechnical requirements to address the needs of each project.

Domestic Market Share

Domestic market share is assessed as medium. The UK has the ability to leverage the experience and capabilities from the shipbuilding and oil & gas industries to take a leading role in anchor supply. The ability to link with development consultancies, particularly seabed surveys, can provide an advantage in designing project-specific solutions as part of up-front engineering design work. However, there will be limitations on the volumes produced in the UK, depending on the types of anchors used. Illustratively, a market size of 100 turbines per year would require 20,000 tonnes of suction piles, which shows the scale of opportunity but also the amount of steel needed to meet such level of demand. UK companies may be better placed to produce drag-embedded anchors (see following case study).

Export Potential

Export potential is assessed as medium. With the appropriate investment in R&D and spreading production between a number of facilities, UK companies have the ability to meet a high proportion of domestic demand and to export. However, the global market is highly competitive, with strong capabilities and established companies particularly in the Netherlands and Singapore, while the steel required is mainly imported from China. The cost of supply and shipping of anchors will be the main decision factor for developers.

Commercial Readiness

UK companies are already producing anchors suitable for commercial-scale floating wind farms. Isleburn Limited (part of Global Energy Group) in the North of Scotland produced 15 suction anchors for the Hywind Scotland project, while Bruce Anchors, headquartered in Aberdeen and with production facilities in Sheffield and Stoke, has capability to produce upwards of 200 drag-embedded anchors per year.

Key Companies with UK Presence

Axis Energy Projects, BiFab, Bruce Anchor, Gael Force, Global Energy Group, Gray Fabrication, Griffin - Woodhouse Ltd, Intermoor, R&M Engineering, Saxton Marine Supplies Ltd, Tension Technology International

5. Mooring lines

% Lifetime Cost (Undiscounted)	Unique to FW (Y/N)	UK expertise (Y/N)	Domestic Share (High/ Medium/ Low)	Export potential (High/ Medium/ Low)	Commercial readiness (Y/N)
2%	N	Y	Medium	Medium	Y

Scope of Services

Design and manufacture of mooring lines and connectors, including chain, rope, synthetic tendons, steel tendons.

Unique to Floating Wind

Mooring lines commonly used in the oil & Gas and shipbuilding industries are chain and synthetic rope mooring systems. For floating wind, chain is currently the first option although larger cross-section areas of chain are required compared to typical oil & gas or shipping solutions. There is an opportunity for increased partnership between mooring and anchor suppliers to develop holistic, optimised mooring system solutions mooring systems solutions.

Existing UK Expertise

UK suppliers of mooring lines exist but are mainly undertaking design contracts with the manufacturing being mostly located overseas. Synthetic ropes are widely used in oil & gas and new materials, including nylon, are currently being tested for floating wind. More opportunities can arise for the UK if synthetic ropes become proven solutions, exploiting UK expertise in mooring analysis and design. Spain, China and Poland are key competing countries in terms of cost on mooring lines.

Domestic Market Share

Domestic market share is assessed as medium. It is unlikely that UK will become cost-competitive in manufacture of steel chain. Some moorings suppliers have estimated that, for chain moorings, 100 turbines per year could require approximately 120,000 tonnes of chain – approximately 20% more than the capacity of the largest existing Chinese plant. However, there is strong logic for further development of synthetic moorings, especially to provide mooring solutions configured as anchor-chain-synthetic-chain, which will allow minimal use of heavy, imported steel and can be assembled onshore at site before installation.

Export Potential

Export potential is assessed as medium. Potential is currently low due to the prevalence of chain moorings and the lack of logic for UK exports due to production and transportation costs. However, if synthetic ropes are more widely adopted, then the UK can be placed as a leader in design and supply of mooring systems. UK development in manufacturing of synthetic mooring lines could fill the gap in the market which is not currently served by the existing global capacity.

Commercial Readiness

UK suppliers can already source moorings suitable for commercial-scale windfarms. However, further development and testing is required of the synthetic materials which can provide UK companies with a domestic and export advantage.

Key Companies with UK Presence

Axis Energy Projects, Bridon Bekaert, Caley Ocean Systems, Gael Force, James Fisher Marine Services, Mooring Systems Limited, Offspring International, Reel Group, Saxton Marine Supplies Ltd, Tension Technology International

6. Electrical Infrastructure

% Lifetime Cost (Undiscounted)	Unique to FW (Y/N)	UK expertise (Y/N)	Domestic Share (High/ Medium/ Low)	Export potential (High/ Medium/ Low)	Commercial readiness (Y/N)
8%	N (array cables and substation) Y (dynamic export cables)	Y (array cables and substation) N (dynamic export cables)	Medium	Medium	Y

Scope of Services

Electrical infrastructure includes array cables, export cables and offshore substation.

Unique to Floating Wind

The electrical topside will be largely unchanged for floating substations.

Static cables requirements (both array and export) are identical to those for bottom-fixed offshore wind.

Dynamic cables are available at the sizes required for array cabling (eg. 33kV), but dynamic cables large enough for export to shore (eg. 220kV and higher) have not yet been developed.

Existing UK Expertise

The electrical systems for top-side of UK offshore substations are already mostly designed and built in the UK.

There is a strong UK expertise in design and manufacture of array cables, and electrical connectors.

The UK currently has no capability for export cables.

Domestic Market Share

Domestic market share is assessed as medium. UK companies can be expected to maintain a similar share of the domestic market in substation topsides and array cables for floating wind as experienced to date in bottom-fixed offshore wind. However, there is no clear pathway for UK companies developing capability in export cables, either static or dynamic, which is a high-value component.

Export Potential

Export potential is assessed as medium.

There is limited opportunity in topside design and manufacture, where knowledge of local standards and requirements can be beneficial and most electrical OEMs are non-UK, so fabrication can be distributed across their facilities overseas to minimise costs.

Export opportunities exist in array cables and electrical connectors. There are still relatively few cable suppliers around the world, including 2 in the UK (JDR in Hartlepool and Prysmian in Wrexham). UK firms are at least as far advanced as any others in the development of 66kV dynamic cables.

As with the domestic market, there is no clear pathway for UK companies developing capability in export cables, either static or dynamic, which is a high-value component.

Commercial Readiness

UK companies are well placed to meet market needs in electrical topsides and static and dynamic array cable. Dynamic export cables are likely to be developed elsewhere.

Key Companies with UK Presence

AEI Ltd., Atkins, Babcock, JDR Cable Systems Ltd, Hydratight, Hydro Group and HydraSun, Oceaneering, Prysmian, Siemens Manchester, Wood

7. Port & Logistics Infrastructure

% Lifetime Cost (Undiscounted)	Unique to FW (Y/N)	UK expertise (Y/N)	Domestic Share (High/ Medium/ Low)	Export potential (High/ Medium/ Low)	Commercial readiness (Y/N)
3%	N	Y	High	Low	N

Scope of Services

Staging of substructure and turbine assembly activities.

Unique to Floating Wind

Many of the requirements are similar to those for bottom-fixed offshore wind and oil & gas. Different types of substructures have different port requirements. Spars require extensive quayside draft or deep-water sheltered area for turbine mating (similar to Hywind Scotland being mated off Norway and towed to Scotland). Semisubmersibles, barges and TLP's require appropriate slipway, floating quay or dry docks for full assembly and launch, with semisubmersibles and barges also requiring large quayside areas (up to 80m x 80m).

Existing UK Expertise

Green Port Hull and Nigg Energy Park in Scotland are good examples of UK manufacturing hubs for the offshore wind industry near the coast, which are already working with offshore wind projects. Kishorn Port in the North West of Scotland has received investment in order to be used as the construction port for the Kincardine floating wind project Other existing large facilities widely used in oil & gas are shipyards such as Rosyth, Clyde, Devon, Cromerty, Scapa and Lerwick.

Domestic Market Share

Domestic market share is assessed as high. There is a very strong logic for local supply and the UK has a number of ports actively looking at upgrading facilities to be ready for floating wind (see following case studies). Some of these are located in regional clusters near to offshore sites identified for floating wind development. The ability to meet high volume requirements in time is the main driver behind the decision for fabrication and assembly locations in floating wind projects. Industry engagement indicates that, with a firm future pipeline for floating wind projects, new investments in fabrication and assembly facilities could be realised, giving the opportunity to the UK supply chain to compete with the main manufacturing and assembly companies from Continental Europe. There will be restrictions on the type of substructures which can be installed in many ports due to draft limitations – Norway is a natural competing country for assembly of spars.

Export Potential

Export potential (ie. Using UK ports for staging floating wind projects based overseas) is assessed overall as low. This assessment is based on the importance of locality. In addition, cost is the main driver in deciding the location of fabrication and assembly facilities and the competition with other countries is significant with France, Netherland and Denmark being more price-competitive. However, as with substructure fabrication, proximity makes Ireland a potential export market.

Commercial Readiness

Proximity to offshore wind sites and to other key global ports is key as components may be fabricated and shipped to ports from all over Europe. However, not many large areas next to the coasts are suitable for construction so there will be constraints on meeting volume requirements in time for commercial-scale projects. Dry dock facilities were originally constructed for long and slender naval vessels so the majority of them are not large enough to accommodate wide floating wind platforms and may require deeper quayside draft. Modifications are needed to make existing ports suitable for serial production and storage.

The types of substructure finally selected to be deployed will define the extent of improvements required in each port. New load out means should also be developed and/or installed in ports adopting some experience from oil & gas, shipping and bottom-fixed offshore wind.

Investment in the order of £30m - £50m across a number of ports is required in facilities to enable assembly and storage on site.

Key Companies with UK Presence

A&P Tyne Limited, Associated British Ports (ABP), EastPort UK, Cammell Laird Shipyard, Falmouth Port, Global Energy Group, Grimsby – ABP, Harland & Wolff, Harwich Navyard, Kishorn Port & Drydock, Montrose Port Authority, Peel Ports (Hunterston), Pembroke Port, Rosyth, Port of Mostyn, Port of Sunderland Authority.

8. Cranes

% Lifetime Cost (Undiscounted)	Unique to FW (Y/N)	UK expertise (Y/N)	Domestic Share (High/ Medium/ Low)	Export potential (High/ Medium/ Low)	Commercial readiness (Y/N)
1%	N	Y	Low	Low	Y

Scope of Services

Large ring cranes for onshore turbine mating, major repairs and decommissioning; smaller crawler cranes for on-site manufacturing and assembly.

Unique to Floating Wind

Floating wind foundations and turbines will be assembled at the quayside and towed to site. Pre-commissioning of wind turbine is unique to floating wind with some parallels being drawn from other industries of ship building and oil & gas.

Existing UK Expertise

There is a strong presence of the largest lifting companies in the UK, however, the largest crane equipment is often sourced from overseas.

Domestic Market Share

Domestic market share is assessed as low. There is currently no capability for the cranes to be used in commercial floating wind projects although a limited number of cranes is available for the current size of wind turbines.

Export Potential

Export potential is assessed as low. This potential can be increased if existing UK companies pursue a strong interest in floating wind, since crane companies in other markets are also in the position of having to develop the class of crane required – with the development and testing period typically being around 2 years.

Commercial Readiness

Very few heavy lift cranes currently exist that have the appropriate capacity to perform wind turbine assembly at port (and for O&M repairs). Weight is not an issue as there are available cranes in the market which can deal with heavy components of over 500 tonnes. Limitations are observed in the height specifications which require lifting over 120m. Feedback from crane operators is that, with the right market signals, the appropriate class of cranes will be developed and made available.

Key Companies with UK Presence

Ainscough, ALE, Mammoet, Weldex

9. Installation

% Lifetime Cost (Undiscounted)	Unique to FW (Y/N)	UK expertise (Y/N)	Domestic Share (High/ Medium/ Low)	Export potential (High/ Medium/ Low)	Commercial readiness (Y/N)
3%	N	Y	High	Medium	Y

Scope of Services

All offshore installation operations: anchor and mooring installation; cable installation; substation installation; and towing substructure and turbine to site.

Unique to Floating Wind

Installation procedures may differ between the floating wind typologies. In terms of multi-purpose vessels, floating wind requirements are not unique. Seabed conditions can create an extra burden for some typologies in anchors and cables installation. For example, anchors in TLPs are sensitive to soil conditions increasing the risk and thus cost of installation. Expertise from bottom-fixed offshore wind is easily transferable and there is no need for bespoke vessels.

Tugs and anchor-handling vessels (AHV's) are usually selected for tow-out as well as for electrical and mechanical coupling and mooring systems. Heavy-lift vessels (HLV's) are selected for offshore substations. Final wind turbine commissioning which must be done at site is performed using crew transfer vessels (CTV's) and service operation vessels (SOV's). Cable laying vessels are used for electrical cable installation.

Existing UK Expertise

The UK installation fleet provides a strong offer in both cost and quality, and the technology used in installation services shows similarities with the oil & gas industry and shipping where multi-purpose vessels are commonly used and there are important hubs on the East coasts of England and Scotland.

Domestic Market Share

The domestic market share is assessed as high. The UK has a strong base and UK companies are considered highly competitive on quality and competitive on cost. A floating wind market will be attractive to offshore contractors, both in its own right, and for smoothing out the peaks and troughs in the oil & gas industry. A number of other counties, such as the Netherlands, Belgium and Germany also have strong capabilities and are cost-competitive, meaning that some share of the UK market will go to overseas contractors.

Export Potential

The export potential is assessed as medium. The types of vessels already described are readily available in European floating wind markets and there is strong competition from companies based elsewhere in in Europe. With Asia and the USA, the distances involved means that export is likely to be restricted to skills and engineering equipment rather than vessel use. Despite the global competition, the track record of installation contractors is a significant factor driving developers' contracting decisions. Early project collaboration between developers and third parties can lead to improved solutions and better risk management reducing associated costs. If relationships between UK installers and developers are established, then this can be an opportunity for UK exports. Winning a share of the export market is consistent with expectations based on existing expertise in oil & gas, marine energy and other maritime industries.

Commercial Readiness

The vessels and skills required for commercial-scale floating wind projects are available in the UK and elsewhere. The installation of electrical cables for Hywind Scotland was carried out by UK company Subsea7.

Key Companies with UK Presence

Subsea7, 4subsea, Bibby Offshore, Delta Marine, Fugro, Green Marine, Global Marine Systems Ltd, JPS, Leask Marine, MPI Offshore Ltd, Offshore Marine Management Ltd, Scotmarine, Seajacks, Siem Offshore

10. Operations & Maintenance

% Lifetime Cost (Undiscounted)	Unique to FW (Y/N)	UK expertise (Y/N)	Domestic Share (High/ Medium/ Low)	Export potential (High/ Medium/ Low)	Commercial readiness (Y/N)
24%	N	Y	High	Medium	Y

Scope of Services

Routine inspection and proactive maintenance of turbines and all balance of plant; minor repairs carried out at site and major repairs requiring tow to shore or mobilisation of HLV or jack-up vessels.

Unique to Floating Wind

Much of the routine inspection and proactive maintenance will be very similar to bottom-fixed offshore wind. The key difference is in the expectation of being able to tow turbines back to port in order to carry out major repairs at the quayside though, depending on substructure type and port facilities available, this may not be possible and repair will be carried out offshore.

Existing UK Expertise

The UK is now a well-established base for offshore wind O&M and marine energy. In particular, there are hubs in Hull, East Anglia, Barrow-in Furness and Belfast, with expected growth in the North-East and East of Scotland with the current construction and development of major offshore windfarms. In addition to offshore wind expertise, the UK has capabilities in AHV's, CTV's, SOV's and tugs, and expertise in coupling and de-coupling offshore structures from moorings.

Domestic Market Share

Domestic market potential is assed as high. The 2017 RenewableUK report[21] into UK content in UK offshore wind found that operating expenditure includes 75% UK content, illustrating the UK's strong position. This is expected to continue for floating wind, building on the UK supply chain's entrenched position in offshore wind and expertise in oil & gas.

Export Potential

Export potential is assessed as medium. There is strong logic for local servicing, which will drive ports near to site to be used as operating bases. There are global export opportunities for UK O&M companies by being among the first to address the key challenges relating to floating wind. The access challenges can increase the need for remote operation solutions particularly for inspections but also for some routine maintenance. These are likely to take the form of remote operated vehicles (ROV's) and drones. Solutions already being developed in the UK for bottom-fixed offshore wind will become increasingly valuable in floating wind. Focus on remote control (drones, AUVs) is growing in recent years and public funding is provided in the area of robotics to commercialise innovative ideas which could have applications in several industries including floating wind. In addition, there are also opportunities to provide vessel and personnel expertise in European markets, though these opportunities are likely to limited in Asia and the USA due to geographical restrictions.

Commercial Readiness

Vessels and skills required for O&M of commercial-scale floating wind projects are available in the UK and elsewhere. The ability to perform major repairs at quayside should follow the development work required to make ports suitable as construction bases.

Key Companies with UK Presence

3sun Ltd., Babcock, Bay Towage, Bilfinger, Briggs Marine & Environmental Services, CWind Ltd, DeepOcean 1 UK Ltd, Delta Marine, ElecTech Solutions Ltd, Fugro Seacore Limited, Green Marine, Houlder, Hughes SSE, James Fisher Subsea, Leask Marine, MPI Offshore Ltd, Petrofac, Quoceant, RES

[21] Offshore Wind Industry Investment in the UK

Offshore, Scotmarine, SeaEnergy, Seajacks UK Ltd, Sealion Shipping Ltd, Siem Offshore Contractors, Tidal Transit Ltd., Wildcat Marine Limited, World Marine Offshore

11. Decommissioning

% Lifetime Cost (Undiscounted)	Unique to FW (Y/N)	UK expertise (Y/N)	Domestic Share (High/ Medium/ Low)	Export potential (High/ Medium/ Low)	Commercial readiness (Y/N)
3%	N	Y	Medium	Low	Y

Scope of Services

Removal of turbines and balance of plant from site and onshore disposal or recycling of materials.

Unique to Floating Wind

The decommissioning process will be similar to that for offshore oil & gas platforms, with the key difference being the requirement to decommission multiple units from a single site.

Existing UK Expertise

Experience in oil & gas decommissioning as well as expertise in installation and O&M processes of uncoupling turbines from cables and moorings.

Domestic Market Share

Domestic market share is assessed as medium. UK contractors can be expected to gain a large share of the offshore work, but it is likely that substructures and other components will be shipped to Eastern Europe or Asia to be re-purposed, scrapped or otherwise recycled.

Export Potential

Export potential is assessed as low. The vessels and skills required are readily available in the markets where required and there is limited interest from UK ports in the onshore element of decommissioning, due to the low value of activity and relatively high burden of permitting required.

Commercial Readiness

Knowledge from shipping can assist in forming floating wind decommissioning plans. While there is still a need to develop the class of cranes required for turbine assembly, this does not necessarily restrict the ability to perform safe decommissioning of commercial-scale floating wind.

Key Companies with UK Presence

4subsea, Bibby Offshore, Delta Marine, Fugro, Global Marine Systems Ltd, Green Marine, JPS, Leask Marine, MPI Offshore Ltd, Offshore Marine Management Ltd, Scotmarine, Siem Offshore Contractors, Subsea7

Appendix 5 – Scenario UK Content Assumptions for 2031 and 2050

Supply Chain Segment	Scenario 1 (Maximum potential)		Scenario 2 (Medium Potential)		Scenario 3 (Minimum Potential)	
2031 Market Share	**UK Market**	**Export**	**UK Market**	**Export**	**UK Market**	**Export**
Development Services (PM, Development and Consenting, Surveys, Certification)	75%	32%	75%	12%	38%	6%
Substructure (steel or concrete including substation)	40%	0%	20%	0%	10%	0%
Wind turbine	33%	0%	17%	0%	10%	0%
Anchors	30%	6%	15%	4%	8%	2%
Mooring lines	30%	6%	15%	4%	8%	2%
Electrical infrastructure	39%	1%	20%	1%	11%	0%
Ports & Logistics	60%	0%	30%	0%	15%	0%
Cranes	60%	0%	30%	0%	15%	0%
Vessels and subsea	60%	18%	30%	18%	15%	9%
Other Capex	66%	10%	40%	6%	22%	3%
Capex (weighted by value)	**41%**	**3%**	**22%**	**2%**	**11%**	**1%**
Major & minor repairs	73%	14%	73%	12%	37%	6%
Other Opex	73%	14%	73%	6%	37%	6%
Opex (weighted by value)	**73%**	**14%**	**73%**	**11%**	**37%**	**6%**
Decommissioning	**50%**	**7%**	**25%**	**6%**	**13%**	**3%**
Lifetime	**57%**	**9%**	**46%**	**5%**	**20%**	**3%**

Table 9: UK Content Assumptions 2031 by Scenario

Supply Chain Segment	Scenario 1 (Maximum potential)		Scenario 2 (Medium Potential)		Scenario 3 (Minimum Potential)	
2050 Market Share	**UK Market**	**Export**	**UK Market**	**Export**	**UK Market**	**Export**
Development Services (PM, Development and Consenting, Surveys, Certification)	80%	45%	75%	14%	39%	7%
Substructure (steel or concrete including substation)	60%	0%	30%	0%	15%	0%
Wind turbine	40%	0%	20%	0%	10%	0%
Anchors	50%	9%	25%	4%	15%	2%
Mooring lines	50%	9%	25%	4%	15%	2%
Electrical infrastructure	42%	1%	20%	1%	11%	1%
Ports & Logistics	75%	0%	35%	0%	19%	0%
Cranes	75%	0%	35%	0%	19%	0%
Vessels and subsea	75%	25%	40%	22%	19%	11%
Other Capex	75%	15%	40%	7%	20%	4%
Capex (weighted by value)	**52%**	**4%**	**26%**	**2%**	**14%**	**1%**
Major & minor repairs	85%	20%	80%	14%	43%	7%
Other Opex	85%	20%	73%	7%	37%	4%
Opex (weighted by value)	**85%**	**20%**	**78%**	**13%**	**38%**	**6%**
Decommissioning	**60%**	**10%**	**30%**	**7%**	**15%**	**4%**
Lifetime	**65%**	**10%**	**49%**	**6%**	**22%**	**3%**

Table 10: UK Content Assumptions 2050 by Scenario

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