FLOATING OFFSHORE WIND CENTRE OF EXCELLENCE

Delivered by CATAPULT Offshore Renewable Energy

FLOATING OFFSHORE WIND CENTRE OF EXCELLENCE

STRATEGIC INFRASTRUCTURE AND SUPPLY CHAIN DEVELOPMENT

Summary Report

In Partnership with ARUP

Disclaimer

Acknowledgements

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PREFACE

The Floating Offshore Wind Centre of Excellence (FOW CoE) was established by the Offshore Renewable Energy (ORE) Catapult in 2019 to accelerate the commercialisation of floating offshore wind. The FOW CoE is a collaborative programme working with industry, Government, academic and supply chain partners to ensure floating offshore wind plays a key role in delivering a cost-effective Net Zero, whilst driving economic growth – within the UK and beyond.

The programme was established to address the specific opportunities and challenges the UK faces in developing floating offshore wind. There is the opportunity for the development of the UK market to lead the world and in doing so, support floating offshore wind to have a significant global impact on reducing carbon emissions whilst supporting UK economic growth.

Over the first two years, partners have committed more than £5.5m in funding and supported the development and delivery of more than 25 projects. Through these projects, the FOW CoE delivers evidence and guidance to partners and stakeholders regarding the commercialisation of floating offshore wind. Working across four workstreams – technology, supply chain and operations, development and consenting, and delivering Net Zero (policy) - the multi-disciplinary structure of the programme reflects the diverse and inter-related topic areas key to commercialisation and broader industrial strategy.

The project was delivered by the ORE Catapult and ARUP with the support of the FOW CoE partners and extensive stakeholder engagement. The project was also supported by Scottish Enterprise who provided part of the funding for this project. This report provides a high-level summary of the project's approach, findings and recommendations.

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Nomenclature

AHV	Anchor Handling Vessel
CAPEX	Capital Expenditure
CCS	Carbon Capture and Storage
CFC	Collaborative Framework Charter
CfD	Contract for Difference
CoE	Centre of Excellence
EEZ	Exclusion Economic Zone
FID	Final Investment Decision
FIDER	Financial Investment Decision Enabling in Renewables
FLOWMIS	Floating Offshore Wind Manufacturing Investment Support
FOW	Floating Offshore Wind
FOWT	Floating Offshore Wind Turbine
FTE	Full-time Equivalent
GVA	Gross Value Add
HV	High Voltage
INTOG	Innovation and Targeted Oil and Gas
MCA	Multi-Criteria Analysis
OEM	Original Equipment Manufacture
ONS	Office for National Statistics
ORE	Offshore Renewable Energy
OPEX	Operational Expenditure
OWMIS	Offshore Wind Manufacturing Investment Support
O&G	Oil and Gas
O&M	Operations and Maintenance
RAB	Regulated Asset Base
SHA	Statutory Harbour Authority
SIA	Strategic Infrastructure Assessment
SIC	Standard Industrial Classification
SNIB	Scottish National Investment Bank
SPMT	Self-Propelled Modular Trailer
UKIB	UK Infrastructure Bank

1 EXECUTIVE SUMMARY

Context
Floating offshore wind will play a key role in the UK delivering a cost-effective net zero. Critical to the deployment of floating offshore wind is the development of key enabling infrastructure. Developing appropriate infrastructure in the UK will reduce project cost and risk, and be critical to securing significant UK Gross Value Add (GVA) in UK projects. In the context of the UK floating offshore wind opportunity, developing appropriate infrastructure for the manufacture and assembly of substructure components and marshalling and assembly of Floating Offshore Wind Turbines (FOWTs) and substructures is critical.

In this context the ORE Catapult's Floating Offshore Wind Centre of Excellence (FOW CoE) has undertaken a project to identify and quantify the key infrastructure and supply chain requirements to deliver a pipeline of large scale floating offshore wind projects cost effectively across the UK and with a significant share of project activity based in the UK. It has then related these requirements to existing infrastructure and supply chain capability to identify and quantify development needs. Where development needs exist, an overview of how these might most cost effectively be addressed has been completed – outlining physical infrastructure development needs, supply chain development needs, associated business and investment cases which utilise (where possible) existing private, Government and other stakeholder strategic investment mechanisms. A number of detailed project reports were produced and made available to the FOW CoE partners. In addition, this public summary report has been prepared to provide a high level overview of the project's approach, findings and recommendations.

Offshore Wind Deployment Scenarios
Whilst the UK has established world leading Net Zero targets within which offshore wind will play a key role, there is limited visibility regarding the scale and rate of offshore wind deployment across the UK at the regional level beyond 2030. In addition, the short-term targets which do exist, for both fixed and floating wind, require a sharp increase in deployment rates in the late 2020s and without significant investment in the short term, the lack of availability of suitable infrastructure will act as a barrier to deployment in the late 2020s and early 2030s – both in the Celtic Sea and in Scotland. Beyond the early 2030s the average deployment rates will be defined by Government policy and its implementation.

Floating Offshore Wind Infrastructure Requirements
Floating offshore wind project construction, operation, maintenance and decommissioning has a number of specific requirements with respect to the infrastructure required to support the delivery of these activities cost effectively. The most critical requirements relate to the scale and specification of the substructure and FOWT marshalling, assembly and integration facility, where appropriate laydown area, quayside draft, length, bearing capacity, navigational channel depth and width are key. Other key requirements relate to the specification and scale of the facility used to assemble substructures, which may also include a co-located substructure component manufacturing facility. Key requirements at this facility relate to laydown area, quayside draft, length, bearing capacity, navigational channel depth and width and the availability of suitable wet storage facilities. Many of these requirements are similar or the same as those for fixed bottom offshore wind. Where they are differences, the requirements have the potential for broader application in the offshore energy and other industries – for example Oil and Gas (O&G) servicing, decommissioning, onshore and offshore hydrogen production and transportation infrastructure construction and servicing, Carbon Capture and Storage (CCS), cruises, large scale materials handling, import and export etc.

Existing Infrastructure Capacity and Capability

As it stands, the UK does not have the infrastructure capability, or capacity required to support a number of key large scale floating offshore wind project construction activities including steel substructure manufacture and assembly, concrete substructure construction, FOWT and substructure marshalling, assembly and integration. There are however a number of facilities in the UK which are well placed for development to meet the needs of floating offshore wind and other offshore industries. In addition, there is a particular opportunity to develop the capability of manufacturing steel substructure components in facilities collocated with marshalling and assembly facilities which brings both operational and commercial synergies, as well as increasing the share of UK content in UK projects. A similar opportunity exists for concrete substructure construction, albeit this capability is more likely to be temporary and focused specifically on floating offshore wind. Both would also act a key hubs around which clusters of port capacity and capability can be developed.

Investment and Development Requirements

The infrastructure development and investment needs in the UK vary between the three main regions where floating offshore wind can be deployed at scale – Scotland, Celtic Sea and North East England. Across Scotland and the Celtic Sea a total of £2.0-2.5bn of investment is estimated to be required to 2030 to enable the UK to deliver a strong pipeline of floating offshore wind projects, and associated targets, in the short term. The £2.0-2.5bn investment includes a total investment in Scotland of £1bn for port infrastructure and £450-750m for manufacturing facilities, with the capacity to deliver 142 units or 2.5GW annually. A further £400-600m is assumed for investment in port facilities and £150-250m for a manufacturing facility in the Celtic Sea region to create a capacity to deliver 40 units or 700MW annually.

A further investment in port infrastructure of £750-950m and £300-450m in manufacturing facilities would then unlock the capacity and capability to deploy a pipeline of 66 units or 1.2GW of floating offshore wind projects in the North East of England. In both Scotland and North East England this investment would also play a key role in supporting the ongoing deployment of increasingly larger scale of fixed bottom offshore wind projects in these regions. Combined, this capability would be sufficient to support the ongoing strong and steady deployment of projects to 2050, following any of the five pathways outlined by the Climate Change Committee. With increasing international offshore wind deployment targets, some of the manufacturing facilities may also have a role in supporting the delivery of projects in neighbouring markets – for example Ireland and Norway.

Identifying and Addressing Barriers to Infrastructure Investment and Development

A number of barriers exist to unlocking the required investment at the scale and speed required – both for port infrastructure and manufacturing facilities. A number of opportunities have been identified to address these barriers in the short term.

Port Infrastructure

The scale of the development and investment requirements for the major port infrastructure required to support the delivery of the UK’s (fixed and floating) offshore wind targets and broader Net Zero ambition is very significant – with individual infrastructure projects requiring anywhere from £50-500m in investment funding (albeit with larger projects likely to be phased) and taking many years to progress through the planning, development and consenting phases prior to construction beginning. A number of fundamental characteristics of large-scale port development act as barriers to private sector investment at the scale and speed required. Some of these characteristics are “offshore wind specific”, others are associated with major infrastructure development more broadly. As such, conventional private sector investment models alone are very unlikely to deliver the required speed and scale of port development required. However, a number of opportunities exist to address these barriers. In most cases these opportunities are based on models which have been utilised in other sectors where strategic infrastructure development has been facilitated through appropriate public and private investment models.

Long Term Demand – the risk associated with the aggregate medium- and long-term demand for port facilities in a region presents a barrier to large-scale long-term investment in development of these facilities. Reducing this risk has the potential to increase the scale, and extend the acceptable returns period, of private sector investment in port infrastructure itself. In the context of port infrastructure where offshore wind related activities have the potential to play a major role in generating revenue for a port, a significant factor in reducing risk is the visibility of a long-term pipeline of deployment in that region (long term being defined as over a period similar to the investment return period for private sector investment – between 15-25 years). The provision of medium- and long-term regional deployment targets / rates would build confidence in regional offshore wind deployment to 2050. The likelihood is that different technologies (fixed and floating) will be deployed in different regions and hence this will require either explicit or implicit commitments to the deployment of specific technologies in different regions. It should be noted that these deployment targets would also play a key role in supporting the regional development of appropriate grid infrastructure.

Short- and Medium-Term Utilisation – there is a risk associated with the short- and medium-term utilisation of port facilities in a region, where these are strongly linked to offshore wind related activities, and hence its ability to earn revenue to service debt and / or provide an appropriate return on investment. There are two approaches to mitigating this risk.

- The overall risk associated with investment in major port infrastructure development projects can be reduced by managing regional deployment in a manner such that this maximises the utilisation of port infrastructure, and minimises the overall investment requirement, in that region, over the long term. Typically, this requires steady rates of deployment over the long term – as opposed to peaks and troughs in demand. A coordinated approach to leasing, consenting and the administration of revenue stabilisation schemes on a regional basis would achieve this;
- There is an opportunity for the public sector to further reduce the risk to private sector investors further by providing support which directly (guarantees) or indirectly (revenue support mechanisms) underwrite debt repayments should there be periods where a facility is underutilised (including maintaining factory workforce) – both revenue floor or shared pain / gain models could be considered. A range of potential schemes exist which could be deployed in offshore wind including existing schemes such as the UK Guarantees Scheme. Alternatively, a bespoke scheme could be developed for offshore wind which allows funding from a consortium of offshore wind project developers to share some of this risk. This would most effectively be coordinated at the regional level, albeit it is likely Government would need to establish a model which could be deployed consistently, nationally. In the context of offshore wind, where the Government plays a key role in the provision of overall energy policy, leasing, project consents and administration of revenue support mechanisms, redistribution of infrastructure utilisation risk has the potential to maximise the scale and speed of private investment in strategic national port infrastructure;

In addition to the mitigations above which are both aimed at reducing the risk to, and hence maximising the investment from, the private sector, direct grant funding and loans from the public sector are also likely to have a role in supporting development for certain infrastructure projects. Existing economic development banks in the UK including the UK Infrastructure Bank and the Scottish National Investment Bank are well placed to support such developments given their strategic national importance and significant impact on GVA.

Fiscal Incentives and International Competition – the use of the Freeport, Green Freeport and similar mechanisms has the potential to improve the broader business and investment case for major infrastructure development in addition to improving the international competitiveness of facilities and infrastructure;

Manufacturing Facilities
The scale of manufacturing facility investment is typically modest or significant (£50-250m). In general, there is sufficient appropriate private capital available to facilitate the investment in manufacturing facilities where there is a strong medium term market demand for these components in the UK market. However, a number of "offshore wind specific" barriers exist to maximising the scale of private sector investment and / or securing this investment early enough within a market / region to allow facilities to be constructed in advance of need. If not mitigated, these issues will continue to act as barriers to private sector investment in these facilities meaning the facilities will either not be constructed in the UK or the public sector will be required to bridge a funding gap to facilitate construction (and support for training of factory workers). Key barriers and opportunities to address these include:

First Orders – securing first orders is typically key to manufacturing facility development investments reaching Financial Investment Decision (FID). These orders are typically placed by Tier 1 suppliers or directly by project developers after an offshore wind project itself has reached FID and relatively close to project construction starting (~1-2 year). At this stage in the industry's development, the Contract for Difference (CfD) mechanism typically plays a critical role in an offshore wind project securing FID. With the construction and commissioning period of a manufacturing facility similar to, or longer than, the period between project FID and the components being required, a fundamental barrier to investment in manufacturing facilities associated with the UK offshore wind industry exists. There are two potential approaches to addressing this issue.

- Allow project procurement commitments to be enabled (in principle at least) earlier in the development process. This could be by evolving the existing Contract for Difference (CfD) mechanism to allow project developers to place (in principle at least) first orders earlier in the development process. This might be facilitated by a scheme similar to the previous Final Investment Decision Enabling for Renewables (FIDER) scheme, albeit with the potential to retain a competitive financial element or by moving away from a predominantly cost driven competitive auction process for revenue stabilisation. For example, by setting acceptable revenue support levels sufficiently in advance and encouraging competition in other areas which create value – for example the direct creation of new facilities, employment, environmental improvements. Both these options have the potential to allow orders to be placed, facilities to be built and then orders fulfilled in a timescale which works for both the manufacturer and the project developer;

- Implement a scheme to significantly mitigate or underwrite the risk associated with the potential delay in first / early orders being placed at a facility. This could involve both public and private stakeholders. This may be a challenging model to develop for a number of reasons and would likely be highly component / facility specific;

It should be noted that the two broad approaches above do not need to replace existing mechanisms. They could be developed to augment existing processes and made available selectively where a compelling business case by a project(s) can be made with respect to the facilitation of new manufacturing capacity in the UK.

Other Barriers

The barriers outlined above consider the structural, financial barriers faced by the sector. However, there are a range of other softer barriers which need to be addressed to attract the investment in facilities in the UK – particularly manufacturing facilities. Given the very limited levels of large scale steel manufacturing in the UK at present, significant investment will be required in skills and training to support the development of a competitive workforce for facilities. Such schemes are long term in their approach and impact and as such these need to start well in advance of the construction of the facility itself. There is significant international competition for investment in port infrastructure and particularly manufacturing facilities to establish in offshore wind markets. The role of the long term vision for offshore wind deployment and ability to provide a level of certainty (or some underwriting of the risk) associated with revenues for such facilities need to be viewed in an international context, with the UK presenting a strong and internationally competitive offering. These factors, combined with the structural, financial barriers outlined in this report, mean a coordinated approach by Government, stakeholders, regional development agencies and industry will need to be taken to present a clear overview of the specific scale and location of investment opportunities associated with fixed and floating offshore wind in the UK. These can be informed through direct engagement with industry, and specifically those people and organisations who have delivered, or are currently delivering, such investments to ensure lessons are learned and good practice is identified.

Broader Economic Impact

The broader economic impact of strategic infrastructure is significant with a return of between £10-15 for every £1 invested. The analysis undertaken as part of this project highlights the potential economic value from enabling the fabrication, marshalling and assembly of floating substructures in the UK. Capturing the full market in the UK would generate nearly £40 billion in direct and indirect GVA in the period from 2025 to 2050 (averaging over £1.5 billion per year). It would also create nearly 400,000 direct & indirect FTE years, equivalent to permanently employing more than 15,000 FTE over this timeframe. This analysis only includes floating wind substructures and does not account for other industries which may benefit from enhanced port and yard facilities.

This presents a strong case for public sector support for key strategic infrastructure development. However, it is important that public sector support for infrastructure development is strategically targeted and deployed in a manner which maximises the opportunity for significant private sector funding in this area, hence delivering the highest return on investment for the public support committed – both in financial terms but also by having an impact on other Key Performance Indicators such as skills and training development, supply chain opportunity diversification and increased economic resilience of regions.

Recommendations

Short term deployment targets need to be combined with medium- and long-term deployment ambitions on a regional level to determine appropriate and sustainable port infrastructure capacity in those regions for each of the functions described in this report.

Regional "port clusters" should be developed in the short term (2022-2024) around one or more "hub" facilities which can host substructure and FOWT marshalling, assembly and integration for large scale floating offshore wind projects. This is critical enabling infrastructure around which clusters can be built. It may also be desirable to seek to develop manufacturing capacity at this same facility – assuming this allows the facility to retain the required marshalling and assembly capacity. This is likely to improve the business case for the broader port infrastructure investment (by providing stable revenue from long term leasing arrangements with a manufacturer) as well as enhancing the overall offer of the port cluster. In the short term this is required in Scotland and the Celtic Sea. Work in Scotland is already progressing in this area following the publication of SOWEC's Strategic Infrastructure Assessment (SIA) in 2021 and a Collaborative Framework Charter (CFC) in May 2022. It is desirable that the capability, capacity and development needs of these port clusters is clearly articulated to present a strong business case for private and public sector investment.

In the short-term (2022-2024) existing support schemes should be focused on developing port clusters in Scotland and the Celtic Sea, with a specific focus on the hubs. Examples of relevant existing schemes include the OWMIS, FLOWMIS, Freeports and Green Freeports.

The use of the current Freeport and Green Freeport mechanisms has the potential to significantly improve the broader business and investment case for major infrastructure development in addition to improving the international competitiveness of facilities and infrastructure and should be used for this purpose. These schemes offer a short term and significant opportunity to support the development of key enabling infrastructure and manufacturing facilities associated with the offshore energy industries and specifically offshore wind – and have the potential to further leverage any funding provided by the FLOWMIS or similar support schemes in the short and medium term.

To maximise the scale and speed of private sector investment in strategic port infrastructure, a dedicated scheme should be developed in the coming years to support large scale investment in port infrastructure between 2024 and 2028. The primary role of this scheme should be to underwrite risk associated with port utilisation in the short, medium and long term. This could seek to leverage pooled investment from offshore wind developers and the public sector to underwrite risk, with significant private sector investment directly into the infrastructure development – maximising private sector investment. Any scheme should be deployed alongside medium- and long-term regional deployment ambitions and associated implementation of regional leasing, consenting and administration of revenue support.

Any scheme developed above should include consideration of, and / or be coordinated with other activities to address, the softer barriers the UK will face when attracting investment in port and particularly manufacturing facility investment – specifically skills, training and development, and the ability to clearly communicate the opportunities and approach to mitigations of risks in the context of significant international competition for investment.

2 INTRODUCTION

Infrastructure shall play a critical role in the cost-effective delivery of large scale floating offshore wind projects and the creation of UK GVA. Key enabling infrastructure facilitates efficient manufacturing, assembly and project installation activities, as well as reducing weather risk and carbon emissions associated with construction activities. It also acts as a focal point for clusters of relevant industrial activity which creates synergies between supply chain organisations and across supply chain tiers.

In the context of the UK floating offshore wind opportunity, the role of major manufacturing facilities and port infrastructure for marshalling and assembly of substructure components, turbines, mooring and dynamic cable systems as part of project construction activities are particularly important. These activities represent a significant share of the overall project capital expenditure (CAPEX) and with appropriate development, there is a credible opportunity for a substantial part of this work to be delivered by UK-based supply chain.

The scale of future offshore wind technology, and specifically FOW technology, will require the development of larger scale infrastructure to manufacture, transport, dry store, assemble, commission, wet store and maintain this technology wherever these activities are performed. However, it is likely that the most cost-effective way to deploy a pipeline of large scale floating offshore wind projects in the UK will be to have access to appropriate infrastructure within the region projects are deployed in. With the UK targeting up to 5GW by 2030, it is vital that such infrastructure development progresses in the short term and hence is available in advance of need.

To be sustainable, the infrastructure required to support the delivery of FOW projects cannot be specific to FOW projects. This same infrastructure needs to be able to support other relevant offshore industries including the ongoing build out of fixed bottom wind, oil and gas servicing and decommissioning, onshore and offshore hydrogen production and transportation infrastructure construction and servicing, carbon capture and storage etc.

In addition to physical infrastructure, key supply chain capability is also required to effectively utilise such infrastructure, reduce the costs of project delivery and maximise the opportunities for the supply chain. With industry aspirations to deliver an increasing share of UK content in UK projects, and a strategic opportunity for the UK to support the delivery of projects throughout the North Sea, Celtic Sea and Irish Sea, it is vital that appropriate supply chain capability is developed, in tandem with relevant infrastructure.

In this context the ORE Catapult's FOW CoE has undertaken a project to identify and quantify the key infrastructure and supply chain requirements to deliver a pipeline of large scale floating offshore wind projects cost effectively across the UK and with a significant share of project activity based in the UK. It has then related these requirements to existing infrastructure and supply chain capability to identify and quantify development needs. Where development needs exist, an overview of how these might most cost effectively be addressed has been completed – outlining physical infrastructure development needs, supply chain development needs, associated business and investment cases which utilise (where possible) existing private, Government and other stakeholder strategic investment mechanisms.

The project was delivered by the ORE Catapult and ARUP with the support of the FOW CoE partners and extensive stakeholder engagement. This report provides a high-level summary of the project's approach, findings and recommendations.

3 OFFSHORE WIND DEPLOYMENT SCENARIOS

The utilisation of key strategic infrastructure is strongly linked to the rate of offshore wind deployment nationally and regionally. For this reason, it is important to understand both the long-term aggregate deployment of offshore wind in the UK, and the rate and regional distribution of this deployment. This section outlines potential deployment scenarios for UK offshore wind to 2050.

3.1 Aggregate Offshore Wind Deployment Rates

Offshore wind will play a key role in the UK delivering a cost-effective Net Zero. The 6th Carbon Budget from the UK's Climate Change Committee[1] proposes at least 95GW of offshore wind by 2050 in its "Balanced Pathway", with a number of the other pathways suggesting significantly more offshore wind might be required.

CCC Pathway	Balanced Net Zero Pathway	Headwinds	Widespread Engagement	Widespread Innovation	Tailwinds
Renewable generation & capacity[2] in 2050	80% of total Wind: 125GW (95GW offshore) Solar: 85GW	75% of total Wind: 90GW (65GW offshore) Solar: 85GW	85% of total Wind: 130GW (100GW offshore) Solar: 80GW	90% of total Wind: 175GW (140GW offshore) Solar: 90GW	90% of total Wind: 160GW (125GW offshore) Solar: 75GW

Table 1: Climate Change Committee Pathways – Role of Renewable Energy

The UK has established an offshore wind deployment target of 50GW by 2030, including up to 5GW of floating wind. Beyond 2030 no target exists for deployment, but guidance can be taken from the work of the CCC which suggests anywhere between 65GW and 140GW of offshore wind may be required (with a mean target capacity of 105GW across the five CCC pathways). These targets suggest a very sharp increase in deployment in the mid to late 2020s, with the deployment rate in the 2030s and 2040s being defined by future Government policy and associated implementation. Table 2 and Figure 1 outline potential annual average offshore wind deployment rates to 2050.

CCC Pathway	Balanced Net Zero Pathway	Headwinds	Widespread Engagement	Widespread Innovation	Tailwinds
Offshore Wind by 2050	95GW	65GW	100GW	140GW	125GW
2010-2021			~1-2GW/annum		
2022-2030			~3-6GW/annum		
2031-2050[3]	~3GW/annum	1-2GW/annum	~3GW/annum	~5GW/annum	~4GW/annum

Table 2: UK Offshore Wind Deployment Rates

[1] The Sixth Carbon Budget - The UK's Path to Net Zero, Climate Change Committee, 2020.
[2] Variable renewables include wind and solar, including generation for electrolysis.
[3] Includes deployment as part of repowering old projects at an average rate of 1GW/annum. This deployment shall be negligible in the 2020s but will rise to around 1GW/ annum in 2030s and 2040s.

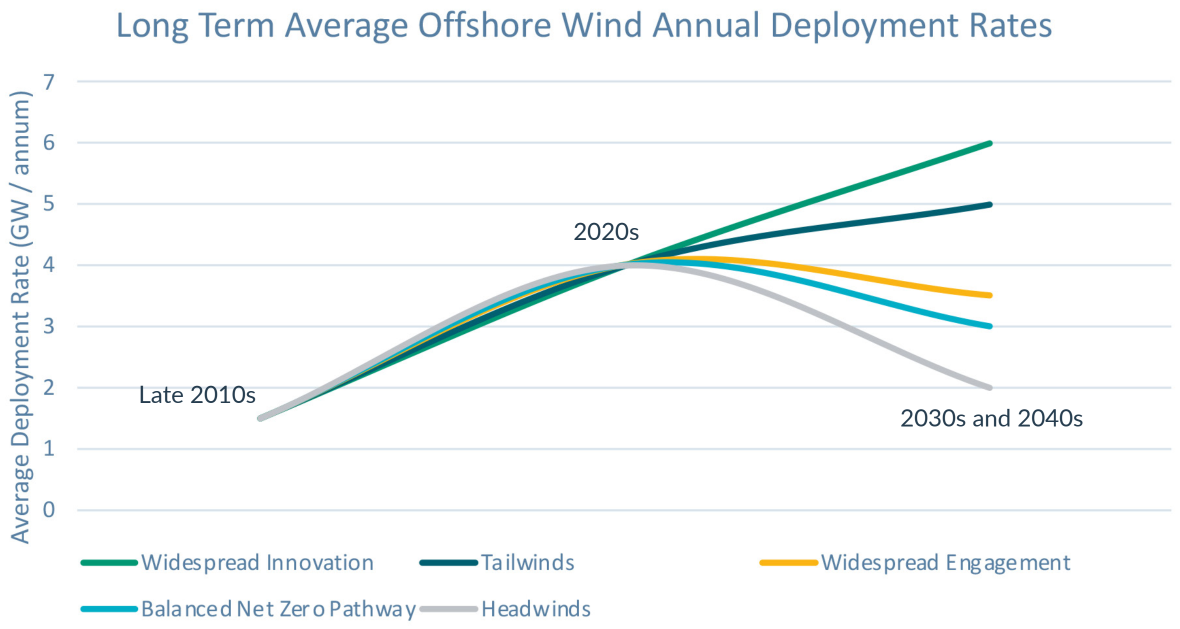

Figure 1: Long Term Average UK Offshore Wind Deployment Rates

The UK has recently increased its deployment target for 2030 from 40GW to 50GW. Delivering this shall require the acceleration of deployment of both fixed and floating offshore wind projects. Delivering the 2030 target will see a significant increase in deployment rates in the late 2020s, most likely followed by a drop in deployment rates. The deployment rate in the early 2030s will be defined by future Government policy and associated implementation.

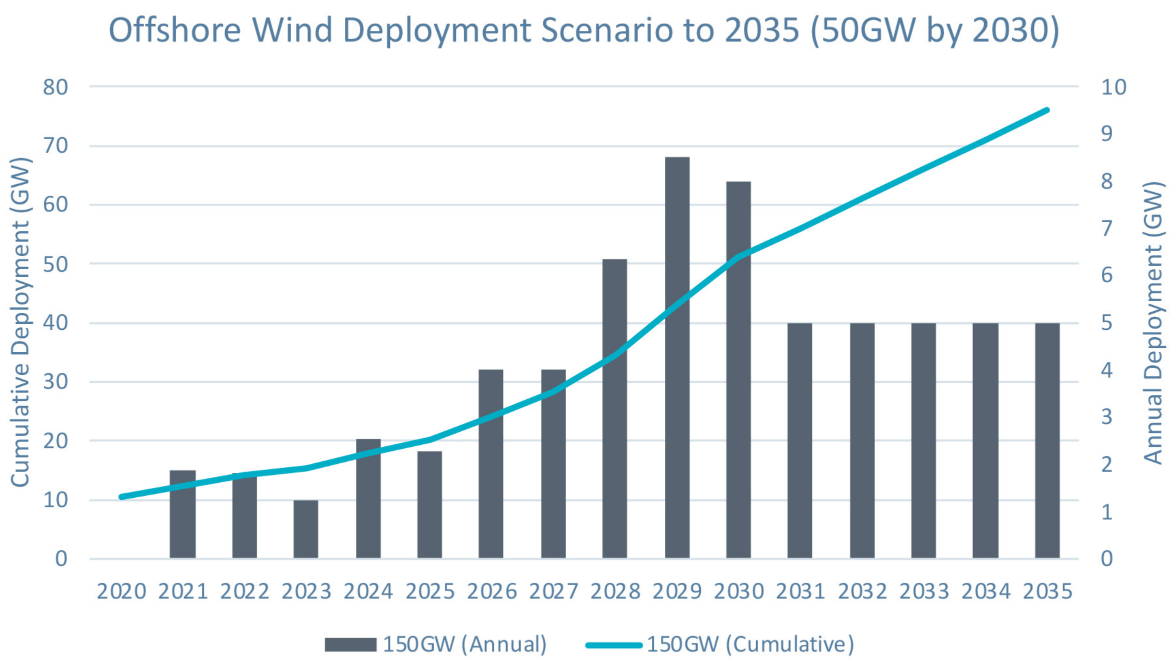

Figure 2: UK Offshore Wind Deployment Forecast to 2035 (50GW by 2030, 150GW by 2050

Figure 2 shows the variability in deployment rates from 2020-2035 on a national level. On a regional level the variability is even more significant.

3.2 Fixed and Floating Offshore Wind Deployment Rates

Within the aggregate deployment of offshore wind to 2050, there is the potential for fixed and floating wind to play differing roles, depending on the future development of these technologies, Government policy and associated implementation. Whilst it is not currently possible to ascertain the split of fixed and floating wind a number of comments can be made regarding the potential role of each in future offshore wind deployment scenarios.

3.2.1 Fixed Bottom Wind

- Until 2030 fixed bottom wind will remain the cheapest form of offshore wind and hence ongoing deployment will be supported through existing and future leasing rounds and revenue support allocations;
- In the 2030s and beyond the scale of fixed wind deployment will become increasingly sensitive to the approach taken to managing and mitigating environmental interactions at the project and regional level, with the potential for fixed bottom projects to face increasing environmental constraints as aggregate deployment levels increase in certain regions;
- In the 2030s and beyond the relative difference in cost between fixed and floating wind is projected to become increasingly small as the cost of floating offshore wind falls sharply. However, the difference will still play a key role in determining the approach taken to supporting fixed and floating wind deployment;
- In the context of the above, it is considered likely that the rate of deployment of fixed bottom wind will begin to level off towards the end of the 2030s as cost effective sites are utilised and aggregate environmental constraints become more significant in regions most suited to fixed bottom wind deployment.

3.2.2 Floating Wind

- Until the early 2030s, the reduction in the cost of floating offshore wind will primarily be driven by the scale of deployment, with innovation playing a key role in reducing risk;
- In the 2030s and beyond, the primary driver of cost reduction in floating offshore wind will be innovation;
- In the 2030s and beyond, the cost of floating offshore wind will be influenced significantly by the choice of sites / areas / regions where it is deployed and the approach taken to the development and management of the offshore transmission system;
- The rate of deployment of floating offshore wind in the 2030s and 2040s shall be strongly linked to any 2050 aggregate deployment targets for offshore wind. With the potential for the deployment of fixed bottom to level off, the rate of deployment of floating wind will rise significantly in the 2030s and 2040s. The rate of this increase shall be driven by the aggregate offshore wind deployment target for 2050.

For the purposes of this study three different aggregate deployment scenarios were considered for UK FOW (see Figure 3).

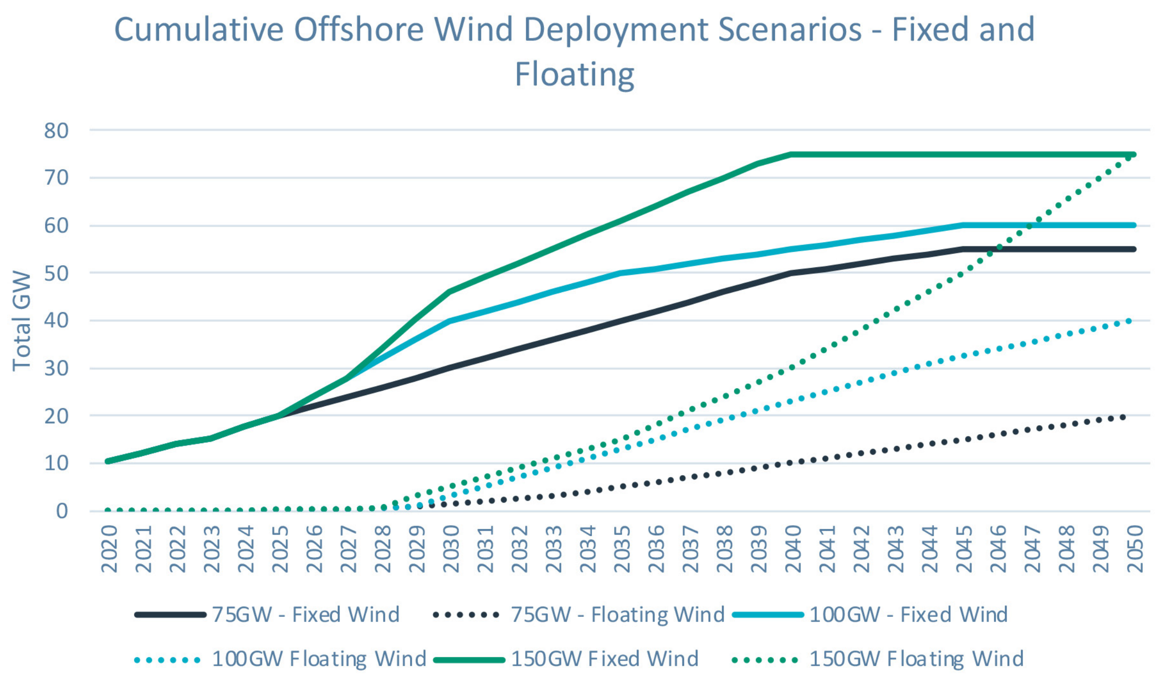

Figure 3: Offshore Wind Deployment Scenarios to 2050

During the course of this project the ScotWind leasing round results were announced and the UK Energy Security Strategy[4] were launched. Both will have profound effects on the deployment of offshore wind to 2035. In the deployment profiles shown above, only the 150GW by 2050 profile sees 50GW of offshore wind and 5 GW of floating wind installed by 2030.

3.3 Deployment Rates and Infrastructure Requirements

The development of appropriate port infrastructure in the UK will enable the UK to deploy a defined amount of offshore wind – fixed or floating – each year. Whilst there are project specific technology and operational factors which influence the capacity a given port can deliver, in a given period of time, it is possible to estimate the capacity of a facility[5] to deliver a defined amount of fixed or floating wind annually, when averaged over the long term.

To most cost effectively develop and sustain the use of this infrastructure, and deploy projects in a region, it is desirable to endeavour to balance port capacity in a region and deployment rates in that region. Where these are well aligned, port infrastructure utilisation is maximised and hence best use is made of the developed infrastructure, and the cost of utilising this facility also has the potential to be reduced for the associated projects. Where there is a mismatch between port capacity and regional deployment there may be fallow periods in port utilisation or periods where there is insufficient capacity in a region to deploy projects. In this case project deployment may be delayed or deployment may happen from ports out with the region – increasing project costs.

For these reasons it is important that a coordinated approach is taken to both infrastructure development and deployment rates in a given region.

[4] British Energy Security Strategy, UK Government, 2022.
[5] For the purposes of this report the terms “infrastructure” and “facilities” are used interchangeably, albeit the term infrastructure has been preferenced.

3.4 Regional Distribution of Offshore Wind Deployment

Floating offshore wind has the potential to be deployed widely across the UK – this includes regions where limited or no offshore wind deployment has happened to date. Figure 4 outlines the three main regions where there is significant potential for floating offshore wind deployment.

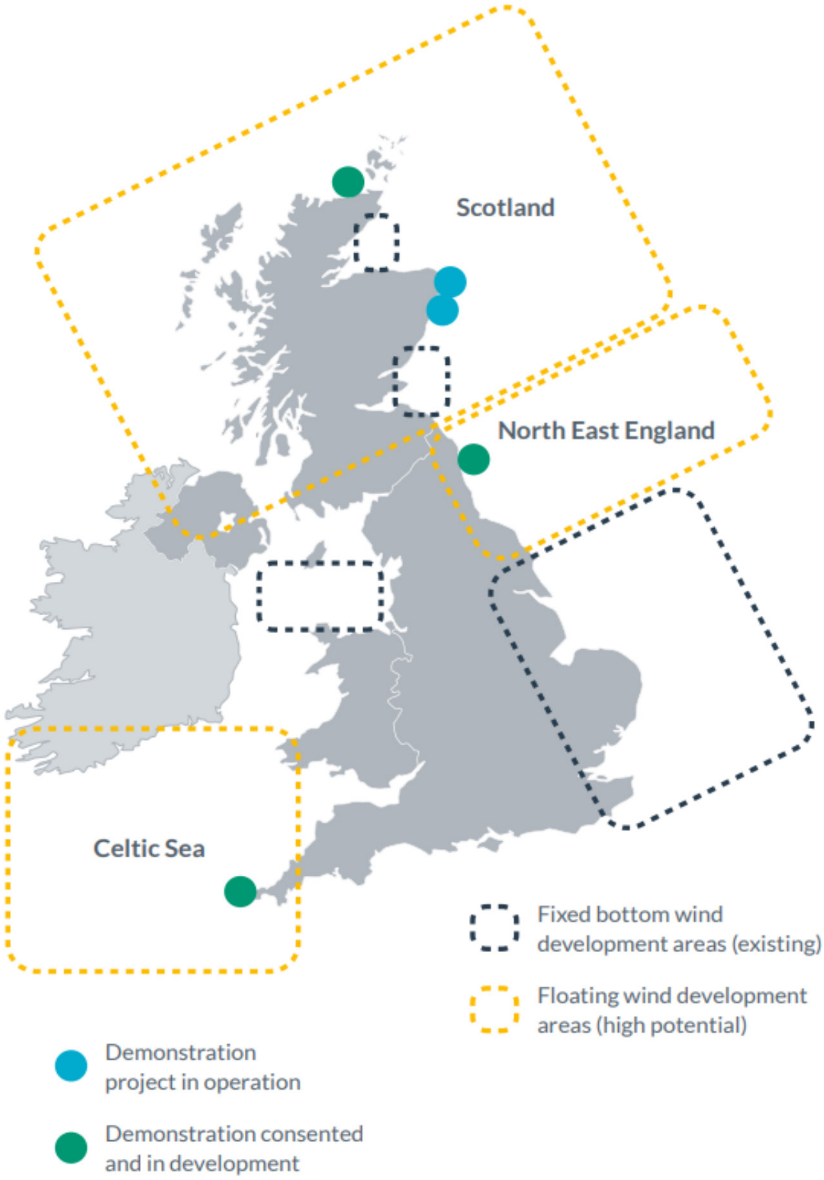

Figure 4: Floating Offshore Wind Deployment Areas

3.4.1 Scotland

Scotland has very significant potential for the deployment of floating offshore wind and has the world's largest pipeline of floating offshore wind projects in development at around 15GW[6]. The entire pipeline of large-scale projects in formal development are all being progressed under the ScotWind process. All ScotWind projects signed a 10-year option agreement in early 2022 which requires them to substantially complete the development and consenting process within a ten-year period. Projects will then enter into a lease agreement with Crown Estate Scotland before commencing the construction phase.

[6] At the time of drafting the ScotWind clearing round was still in progress. This may add further capacity in the N5 zone. If this is the case, this capacity is highly likely to be floating wind.

This pipeline of projects is likely to grow with the award of exclusivity agreements in late 2022 under the Innovation and Targeted Oil and Gas (INTOG) leasing round. Again, these projects are likely to enter into a ten- year option agreement in late 2023 with most having a strong focus on commencing operation within the 2020s (and in time to have an impact on the carbon emission reduction targets in the North Sea Transition Deal[7]).

No targets or policy statements exist to provide guidance on offshore wind deployment past the early 2030s in Scotland, but these are anticipated to be set out in the Scottish Government's refreshed Energy Strategy and Just Transition Plan which will be published later in 2022.

3.4.2 Celtic Sea

The Celtic Sea has the potential for significant floating offshore wind deployment. The Crown Estate are actively developing a leasing round to support the deployment of up to 4GW of floating wind in the Celtic Sea by 2035[8].

No targets or policy statements exist to provide guidance on offshore wind deployment past 2035 in the Celtic Sea in the UK.

The Irish Government has set a target of 5GW of offshore wind by 2030[9]. UK port infrastructure in the Celtic Sea could be well placed to support projects off the Irish Coast.

3.4.3 North East England

The North East of England has the potential for large scale floating offshore wind deployment. At this stage no leasing process exists to access relevant offshore areas in this region for the purposes of large scale floating offshore wind deployment. One demonstrator project is in active development in the region.

No targets or policy statements exist to provide guidance on offshore wind deployment in the North East of England.

3.5 Offshore Wind Deployment Scenarios Summary

Future offshore wind deployment scenarios are required to understand and assess the potential business and investment models for associated strategic supply chain and infrastructure development. Whilst there is a reasonable level of confidence in aggregate deployment scenarios to 2050, there is a significant level of uncertainty associated with these deployment scenarios in the medium term (2035-2040) and on a regional level. As such, it is not possible to be specific about the development requirements in the medium and long term at a regional level. However, deployment scenarios can be used to provide guidance on the potential sensitivity of such business and investment models to the different deployment scenarios, on a national and regional basis.

A strategic approach to offshore wind deployment in the UK has the potential to maximise the utilisation of strategic infrastructure including manufacturing facilities and ports. Maximising infrastructure utilisation will minimise the overall levels of investment required, and the cost of their use, thereby reducing the cost of delivering the projects themselves. Long term regional deployment and strategic infrastructure development plans should be developed which link regional deployment directly to regional infrastructure development and utilisation.

[7] North Sea Transition Deal, UK Government, 2021.
[8] Celtic Sea Floating Wind Programme, The Crown Estate, 2021.
[9] Programme for Government: Out Shared Future, Irish Government, 2020.

4 FLOATING OFFSHORE WIND ACTIVITIES AND ASSOCIATED INFRASTRUCTURE REQUIREMENTS

The role of infrastructure in the development and delivery of a large scale floating offshore wind project varies significantly across the different phases of a project's development, construction, operation and decommissioning. In addition, it will vary depending upon the scale and technical configuration of the project – specifically the choice of substructure design and materials.

4.1 Key Technology Assumptions

Key technical assumptions are outlined below. It should be noted that these are only assumptions at this stage. However, where possible and appropriate commentary is provided in this report regarding how sensitive some findings and conclusions are to these assumptions.

- Large scale floating offshore wind projects in the UK deploy both steel and concrete substructures in significant volumes. There may be a distinct regional difference in the deployment of different substructure designs based on the technical requirements of the projects and the capability and capacity of infrastructure and supply chain in those regions;
- Individual floating offshore wind projects select either steel or concrete foundations. Where both are referenced in this report they are referenced as possible alternatives, rather than indicating that a single project would utilise both;
- Concrete substructure manufacture and steel substructure component manufacture are separate distinct activities which would be done in separate facilities in separate locations;
- Components for steel substructures would be supplied in the required volumes from large steel fabrication / manufacturing facilities which would have the capability to supply large components for floating wind substructures and one or more other relevant applications. Examples include turbine towers, monopiles, jacket foundations, secondary steel structures and vessels. For a given substructure design, a range of large components would be supplied from a range of facilities. These would then be marshalled and assembled into a complete substructure. In the short and medium term, it is highly unlikely that "floating offshore wind specific" steel manufacturing facilities are developed given the range of substructure designs. As such, the designs which are deployed in the short and medium term are being designed to utilise facilities which are also capable of producing components for other applications, and for which there is already a strong medium-term demand;
- Concrete substructure would be predominantly constructed in-situ at a quayside facility, with the potential for some steel and pre-cast concrete components to be supplied from elsewhere. These facilities can be mobilised to an appropriate facility on a temporary basis for a specific project or pipeline of projects in a region – albeit the scale of the project needs to be significant to amortise the mobilisation costs across the units constructed[10];
- Spar buoy substructures are assumed not be used in the UK due to their deep draft;
- By 2030 floating offshore wind turbines between 17.5-20MW will be typical.

[10] Manufacturing concrete Floating Wind Foundations in Scotland, ORE Catapult and Arup, 2021.

4.2 Floating Offshore Wind Project Construction, Operations, Maintenance and Decommissioning Activities

The following sections provide an overview of the floating offshore wind industry's requirements for construction, marshalling, assembly, operation, maintenance and decommissioning facilities based on a set of key assumptions regarding technology development. These have been developed through extensive stakeholder engagement including engagement with project developers, substructure designers, steel fabricators, concrete manufacturers, turbine Original Equipment Manufacturers (OEMs), ports and the broader supply chain.

For the purposes of this project, the turbine manufacturing, offshore substation and fixed bottom foundation manufacturing processes have not been considered in detail with respect to infrastructure requirements. This includes the manufacture of turbine nacelles, blades, towers, High Voltage (HV) substation equipment, monopile and jacket foundations. Each is manufactured in a separate specialist facility.

There are a number of commonalities between the infrastructure requirements for wind turbine tower, monopile and jacket foundation manufacture and the manufacture of steel substructure components. In addition, there are commonalities between the infrastructure requirements for the fixed bottom offshore wind and those required to support floating offshore wind project construction, operation, maintenance and decommissioning. Where this is the case, reference has been made in the appropriate sections of this report.

4.2.1 Floating Offshore Wind Turbine (FOWT) and Floating Substructure Construction

Floating offshore wind turbine and floating substructure manufacture, marshalling, assembly, integration and installation will utilise multiple facilities and ports. The configuration of these will depend on the scale of the project, the substructure design and materials, the capacity and capability of manufacturing and port infrastructure in the region and the availability of this infrastructure during the project manufacture, assembly and construction period.

Figure 5 provides a high-level overview of the key steps in the construction of a large scale floating offshore wind project. This is presented in a manner which identifies how projects of differing configurations and scales might draw on a range of different manufacturing and port facilities.

4.2.2 Mooring Systems Manufacture and Installation

A typical mooring system is comprised of a range of components, each manufactured in specialist facilities. Whilst the scale of these components is significantly less than the turbines and substructures, the volume and scale of these components is still such that it is likely the mooring systems will be marshalled, assembled and installed from a separate facility from the floating wind substructures and turbines themselves.

4.2.3 Dynamic Cable Systems Manufacture and Installation

A typical dynamic inter-array cabling system is comprised of a range of components, each manufactured in specialist facilities. Whilst the scale of these components is significantly less than the turbines and substructures, the volume and scale of these components is still such that it is likely these systems will be marshalled and installed from a separate facility from the floating wind substructures and turbines themselves.

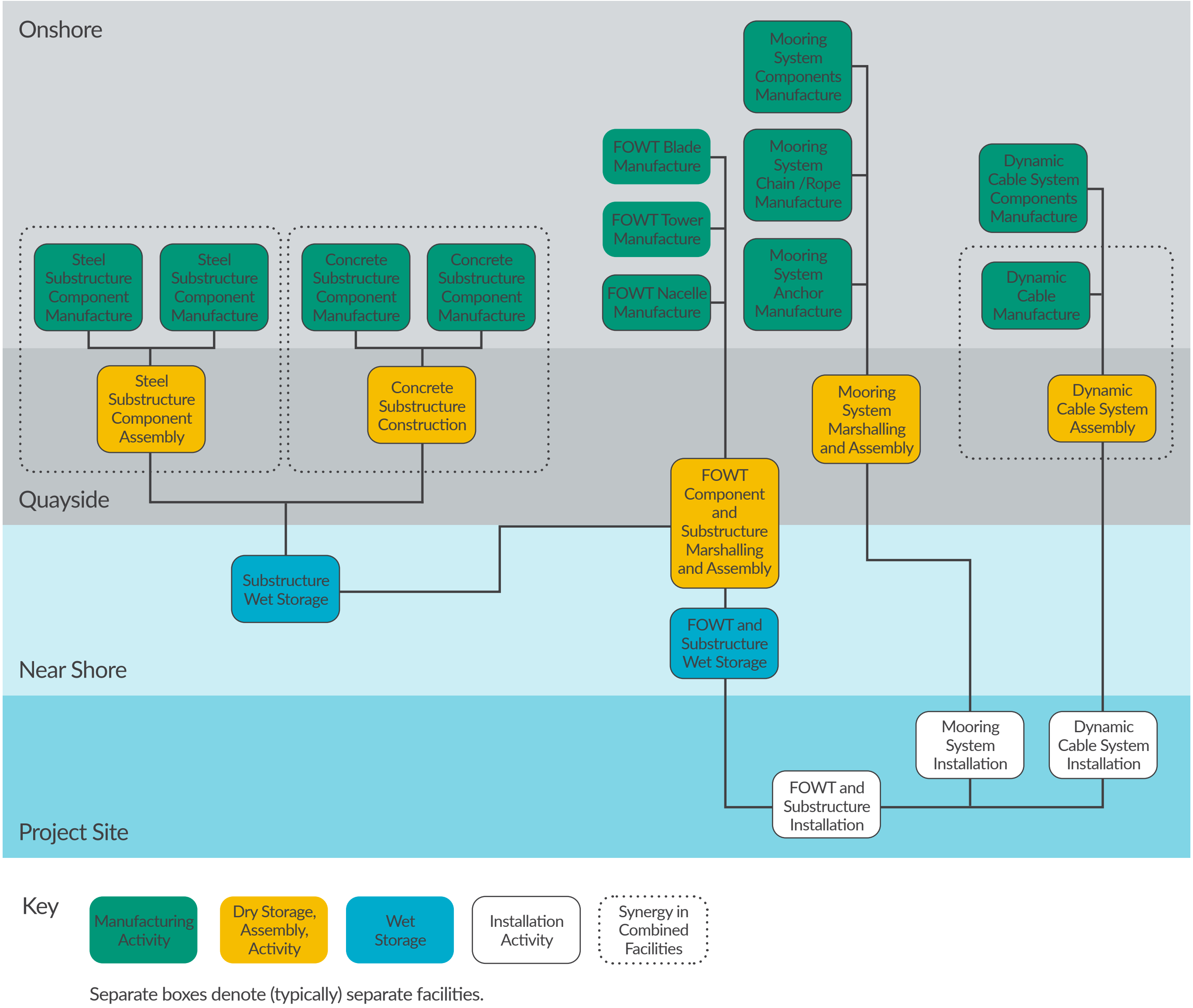

Figure 5: Representative Floating Offshore Wind Project Construction Process

4.2.4 Operations and Maintenance

Following the construction of a floating offshore wind farm, there will be a requirement for ongoing operations and maintenance (O&M) activities. These activities can be broadly split into two different categories – routine maintenance (minor component replacement), and major component replacement.

Floating Offshore Wind Routine Maintenance and Minor Component Replacement - routine maintenance and minor component replacement for floating offshore wind farms will be completed in a similar manner to fixed bottom wind farms. However, given the floating nature of the substructures, some logistical aids may be required to maximise crew, tool and component transfers to / from the turbine. Various logistical aids may also be in place on the substructure and in the turbine to assist safe and efficient movement of technicians and components around the floating offshore wind substructure and turbine. For larger floating offshore wind farms based farther from shore, it is likely that such O&M will be undertaken with the support of a Service Operation Vessel (SOV). This would operate within the wind farm for a number of weeks at a time before returning to an O&M base to change crew, replenish supplies etc.

Floating Offshore Wind Major Component Replacement - major component replacement for floating offshore wind farms is not planned but is likely to be required, as it is in fixed bottom wind. At this stage in the industry's development there are very few vessels in existence which can cost effectively complete a major component exchange operation for a large floating offshore wind turbine. As such, plans for this operation generally and provisionally assume the entire FOWT and substructure would be towed to an appropriate port and / or sheltered water location for the work to be completed there.

4.2.5 Decommissioning

All floating offshore wind farms shall need to be decommissioned at the end of their operational life. As with major component exchange, plans for this operation generally and provisionally assume the entire FOWT and substructure would be towed to an appropriate port and / or shallow water facility for the decommissioning work to be completed there.

4.3 Construction, Operation, Maintenance and Decommissioning Infrastructure

Table 3 to Table 7 outline the key phases of a project's construction, operations and decommissioning. For each phase, high level guidance is provided as to the different infrastructure requirements – both in terms of their specification but also their location. The activities included in these tables are the key phases of construction and do not include various ancillary activities, for example pre- and post-installation surveys, site mobilisations etc.

4.3.1 Floating Offshore Wind Turbine and Floating Substructure Construction Activities

Construction Phase	Facility Type	Location	Transportation	Notes
Substructure component manufacture – steel	Dedicated steel fabrication facility	Coastal strongly preferred for manufacture of large components	Direct access to appropriate road, rail or water links which have capacity to transport largest components manufactured	Component supply likely to come from multiple facilities. Production year round
Substructure component manufacture – concrete	Concrete fabrication facility, temporary or permanent. Likely to combine manufacture and assembly	Anywhere, coastal will be strongly preferred for manufacture of large components and assembly	Direct access to appropriate road, rail or water links which have capacity to transport largest components. Manufacture of large components highly likely to be co-located with appropriate quayside facility	Requires ability to handle bulk materials, with benefit in co-locating with existing supply / handling facilities. Otherwise sufficiently large pipeline required to amortise costs for temporary quayside concrete construction facility. Pre-cast units could be supplied from multiple facilities. Production year round
Substructure component transportation	N/A	N/A	Road, rail or water	Transportation in bulk by water most likely to be cost effective for larger components
Substructure assembly	Marshalling and assembly facility	Coastal, proximity to project site beneficial	Component transportation via Self-Propelled Modular Trailer (SPMT), skids and / or crane	Duration of assembly process critical to defining capacity of marshalling area required. Approach to floater load out also key consideration.
Substructure transportation	N/A	N/A	Towed via Anchor Handling Vessel (AHV), large tug boat or specialist tugs or multiple units loaded onto barge (smaller substructures only)	Transportation over winter period less likely. Desirable to limit the distance of this transit
Substructure "wet storage"	Sheltered coastal waters, appropriate licenses, moorings	Proximity to assembly location or wind turbine integration port desirable	Towed via AHVs, large tug boat or specialist tugs (assuming pre-installed fixed moorings)	Location will require appropriate regulatory permissions and moorings (pre-laid or temporary). Storage may be for weeks / months
Floating offshore wind turbine (FOWT) integration with substructure	Marshalling and assembly facility	Coastal, proximity to project site critical	Quayside crane / jack-up vessel, heavy lift vessel in sheltered water. Vessel and crane dependent on substructure design, equipment availability and / or port facility specification	Duration of assembly process and project logistics are key to defining capacity of marshalling area required. Quayside draft, length, bearing capacity and the depth and width of the navigational channel are key.
FOWT and substructure wet storage	Sheltered coastal waters, with appropriate licenses and moorings	Proximity to wind turbine integration port desirable	Towed via AHV, large tug boat or similar (assuming pre-installed fixed moorings)	Location will require appropriate regulatory permissions and moorings. Permissions distinct from storing units without turbines on. Storage for days only most likely, but could be longer periods.
FOWT and substructure transportation to project site	N/A	N/A	Towed via AHV, large tug boat or similar	Transportation over winter period unlikely. Important to limit the distance of this transit
FOWT and substructure installation	N/A	Project site	Towed via AHV, large tug boat or similar (assuming pre-installed moorings and cables)	Installation over winter period unlikely

Table 3: Floating Offshore Wind Turbine (FOWT) and Floating Substructure Construction Activities

4.3.2 Mooring Systems Manufacturing, Assembly and Installation Activities

Construction Phase	Facility Type	Location	Transportation	Notes
Manufacture of mooring system – chain	Chain manufacturing facility	Highly likely to be coastal	Direct access to appropriate road, rail or water links which have capacity to transport largest components manufactured	Chain storage and handling facilities required for load out. Supply from multiple facilities possible
Manufacture of mooring system – synthetic rope	Synthetic rope manufacturing facility	Anywhere, albeit most likely to be coastal	Direct access to appropriate road, rail or water links which have capacity to transport largest reels	Reel spooling, storage and handling facilities required for load out. Supply from multiple facilities possible
Manufacture of mooring system – components	Mooring component manufacturing facility	Anywhere	Direct access to appropriate road, rail or water links which have capacity to transport largest components manufactured	Supply from multiple facilities likely
Transportation of mooring components to mooring system assembly and load out facility	N/A	N/A	Direct access to appropriate road, rail or water links which have capacity to transport largest components manufactured	Supply from multiple facilities likely
Mooring system assembly at load out facility	Quayside facility with chain / reel handling capabilities	Coastal, proximity to project site beneficial	Quayside facility with direct access to appropriate road, rail or water links which have capacity to transport largest components manufactured	Some anchor types may be transported directly to site and installed using AHVs. Elements of the mooring system assembly likely to happen on installation vessel
Transportation of mooring system to project site	N/A	N/A	AHV with chain locker / reel store	Desirable to pre-install mooring systems at project site. May be done well in advance of FOWT installation
Mooring system installation	N/A	Project site	AHV with chain locker / reel store	Desirable to pre-install mooring systems at project site, installation over summer period preferred but year-round installation feasible

Table 4: Mooring Systems Construction Activities

4.3.3 Dynamic Cable Manufacturing and Installation Activities

Construction Phase	Facility Type	Location	Transportation	Notes
Manufacture of dynamic cable system – cable	Cable manufacturing facility	Anywhere, albeit most likely to be coastal	Direct access to appropriate road, rail or water links which have capacity to transport largest reels	Reel spooling, storage and handling facilities required for load out. Supply from multiple facilities possible but unlikely
Manufacture of dynamic cable system – components	Dynamic cable component manufacturing facility	Anywhere	Direct access to appropriate road, rail or water links which have capacity to transport largest components manufactured	Supply from multiple facilities likely
Transportation of dynamic cable system components to dynamic cable system assembly and load out facility	N/A	N/A	Cable handling vessel, component transport vessel	Supply from multiple facilities likely
Dynamic cable system components assembly and load out	Quayside facility with reel handling capabilities	Coastal, proximity to project site beneficial	Quayside facility with direct access to appropriate road, rail or water links which have capacity to transport largest components manufactured	This facility could be the same as the cable manufacturing facility. Elements of the dynamic cable system assembly likely to happen on installation vessel
Transportation of dynamic cable systems to project site	N/A	N/A	Cable lay vessels with reel	Desirable to pre-install dynamic cable systems at project site
Dynamic cable system installation	N/A	Project site	Cable lay vessels with reel	Desirable to pre-install dynamic cabling systems at project site, installation over summer period preferred but year-round installation feasible

Table 5: Dynamic Cable Construction Activities

4.3.4 Operations and Maintenance Activities

Operations and Maintenance Phase	Facility Type	Location	Transportation	Notes
Load out and transportation of maintenance crew to / from project site	Operations and maintenance base	Coastal, proximity to project site required	Dependent on distance from O&M base to site	Most likely SOV for larger FOW sites farther from shore
Regular maintenance and minor repairs to FOWTs and substructures within project site	N/A	Project site	Dependent on distance from O&M base to site	Most likely SOV (potentially with daughter craft) as FOW sites tend to be farther from shore
Transportation of FOWT and substructure from project site to quayside or sheltered water location	N/A	N/A	AHVs, large tug boat or specialist tugs	Transportation over winter period less likely. Desirable to limit the distance of this transit
Major component exchange / repair at quayside or sheltered water location	(Part of) Marshalling and assembly facility	Coastal, proximity to project site critical	Quayside crane, quayside jack-up vessel, heavy lift vessel in sheltered water	Sheltered water locations would likely require appropriate marine licenses / permissions and moorings. Navigational channel depth and width to location / quayside critical. See also requirements for Floating offshore wind turbine (FOWT) integration with substructure if at quayside
Major component exchange / repair within project site	N/A	Project site	Heavy lift vessel capable of component transport and floating to floating lifts, or alternative lifting equipment capable (e.g. substructure mounted crane) and component transport vessel	Very limited availability of these vessels today but anticipated to become more readily available in future

Table 6: Operations and Maintenance Activities

4.3.5 Decommissioning Activities

Decommissioning Phase	Facility Type	Location	Transportation	Notes
Transportation of FOWT and substructure from project site to quayside or sheltered water location	N/A	N/A	AHVs, large tug boat or specialist tugs	Transportation over winter period less likely. Desirable to limit the distance of this transit
FOWT and substructure decommissioning at quayside or sheltered water location	(Part of) Marshalling and assembly facility	Coastal, proximity to project site desirable	Quayside crane, quayside jack-up vessel, heavy lift vessel in sheltered water	Rate of decommissioning will define required size of decommissioning facility

Table 7: Decommissioning Activities

4.4 Floating Offshore Wind Infrastructure Requirements

4.4.1 Steel Substructure Component Manufacturing

Early demonstration projects have predominately featured steel substructures. These substructures have typically been fabricated in a manner similar to ships and oil and gas platforms, whereby an entire structure is fabricated in situ in a dry dock or on a quayside.

This methodology is not compatible with the scale or efficiency of fabrication that large scale floating offshore wind projects require. As such, larger scale projects which utilise steel substructures, will assemble these substructures from pre-manufactured component parts. These component parts will still be significant in scale but will be manufactured utilising a serial manufacturing process in specialist facilities. These facilities will be similar / the same as the facilities required to fabricate the next generation of offshore wind turbine towers, monopiles etc.

These facilities may be coastal or inland – albeit coastal is strongly preferred as transport of components by sea is typically the most cost effective. Key requirements for the development of these facilities are access to a suitably large site and easy access for transport (road, rail or water) with the capacity for this transport to handle the largest components manufactured at the facility.

4.4.2 Steel Substructure Assembly

A number of demonstrator projects have utilised modular steel substructure designs with substructure assembly being completed at a quayside facility – and with the steel components being manufactured elsewhere. This process is similar to the way large offshore wind turbines are manufactured and assembled, albeit it has typically taken place at a quayside rather than offshore.

The methodology is highly scalable but has some unique requirements with respect to the quayside facility.

These facilities require to be coastal or on large rivers with direct access to the sea. Key requirements for the development of these facilities are access to a suitably large site (for substructure component storage), appropriate specification of quayside and direct access to the sea for the transport complete substructures from the facility. For 20MW turbines, these substructures will have a mass in the region of 4,000[11] tonnes and measure up to 100m by 100m depending on the technology.

There is likely to be a requirement to "wet store" a number of complete floating substructures prior to the floating offshore wind turbines being installed. As such, an appropriate area for wet storage is required either at the substructure assembly facility or at (or on route to) the floating offshore wind turbine integration facility (if different for the substructure assembly facility). This facility shall require appropriate regulatory licences, permissions and moorings.

4.4.3 Concrete Substructure Manufacturing

A number of demonstrator projects have utilised concrete as the primary substructure material. The manufacturing process for concrete substructures is similar to that typically employed in large infrastructure projects such as caisson production, bridges and industrial facilities.

[11] Steel mass only. This figure is indicative only with significant variation in the steel mass / MW for different steel substructure designs.

The manufacturing process for concrete substructures is different from that of steel and shall require different infrastructure / facilities to deliver. Typically the facilities required for large scale concrete manufacturing can be mobilised to an appropriate site specifically for a project or projects. This process includes both the manufacturing of the component parts and the substructure in one location – albeit precast / prefabricated components may also be supplied from elsewhere and integrated as part of this process.

These facilities require to be coastal or on large rivers with deep-water access. Key requirements for the development of these facilities are access to a suitably large site and deep-water quayside access to the sea for transport complete substructures from the facility. For 20MW turbines, these substructures will have a mass of up to 20,000 tonnes and measure up to 100m by 100m depending on the technology.

As with assembled steel substructures, there is likely to be a requirement to "wet store" a number of complete floating substructures prior to the floating offshore wind turbines being installed. As such, an appropriate area for wet storage is required either at the concrete substructure manufacturing facility or at (or on route to) the floating offshore wind turbine integration facility (if different for the concrete substructure fabrication facility). This facility shall require appropriate regulatory licences, permissions and moorings.

4.4.4 FOWT Marshalling, Assembly and Integration

The majority of demonstrator projects have installed the floating offshore wind turbine onto the floating substructure at a quayside facility prior to the complete unit being towed to site for installation. This process is identical to the way large offshore wind turbines are assembled on-site, albeit it takes place at a quayside rather than offshore. The methodology is highly scalable but has some unique requirements with respect to the quayside facility.

These facilities require to be coastal or on large rivers with direct unrestricted[12] deep-water access to the sea. Key requirements for the development of these facilities are access to a suitably large site (for FOWT component storage), appropriate specification of quayside and direct deep-water access (without air draught restrictions) to the sea for the transport complete floating offshore wind turbines and substructures from the facility.

For 20MW turbines, blades are expected to be in the region of 140m, towers of 160m and rotor nacelle assembly of around 1,300 tonnes.

There may be a requirement to "wet store" a small number of complete floating wind turbines and substructures prior to the floating offshore wind turbines being installed at the project site. As such, an appropriate area for wet storage is required either at the substructure assembly facility or at (or on route to) the floating offshore wind turbine integration facility (if different for the substructure assembly facility). This facility shall require appropriate regulatory licences, permissions and moorings.

[12] This primarily refers to the ability of a port facility to maintain full access for vessels irrespective of tidal range, wave height, direction etc. In certain areas of the UK the tidal range is significant which means access can be restricted to certain vessels at certain times of the day, year. To a lesser extent wave height and direction can limit access to certain ports in certain circumstances. Any such restrictions which limit access for floating offshore wind project construction activities add significant risk to project construction schedules.

4.4.5 Chain Manufacturing

Steel chain manufacturing is a fully industrialised process with large facilities in existence across the globe, serving a global market of offshore energy industries. Floating offshore wind has no unique requirements with respect to the specification of a chain manufacturing facility, albeit the scale of demand from floating offshore wind projects may present significant capacity challenges for the existing chain manufacturing supply chain.

Chain manufacturing facilities may be coastal or inland. Key requirements for the development of these facilities are access to a suitably large site and easy access for transport (road, rail or water) with the capacity for this transport to handle the largest chain lengths manufactured at the facility. Chain manufacture is an energy intensive process and as such facilities may be strategically located to benefit from appropriate energy supplies.

For 20MW turbines, anticipated requirements for chain will be project specific but are expected to be in the region of 450kg/m to 700kg/m.

4.4.6 Synthetic Rope Manufacturing

Synthetic rope manufacturing is an industrialised process with facilities in existence across the globe, serving a global market of offshore energies and other industries. Floating offshore wind has no unique requirements with respect to the specification of a synthetic rope manufacturing facility, albeit the scale of demand from floating offshore wind projects will present a significant capacity challenge for the existing synthetic rope manufacturing supply chain.

Synthetic rope manufacturing facilities may be coastal or inland. Key requirements for the development of these facilities are access to a suitably large site and easy access for transport (road, rail or water) with the capacity for this transport to handle the largest (spooled) rope lengths manufactured at the facility.

For 20MW turbines, synthetic rope requirements will be project specific but are expected to be in the region of 35-40kg/m with hundreds of metres of rope required per FOWT.

4.4.7 Mooring System Component Manufacturing

Mooring system component manufacturing is an industrialised process albeit with most manufacturing facilities operating in a “batch manufacturing” rather than serial production mode. In addition, there is a range of mooring system components with most being supplied from different specialist facilities. Examples include anchors, shackles, tensioners, clump weights, buoyancy modules etc. Floating wind may require a number of specialist components, the majority of which are likely to be manufactured at existing facilities. However, a number of these new components are likely to be manufactured in new facilities – examples include specialist anchors, load reduction devices etc. In addition, existing “batch manufacturing” approaches are likely to require development to deliver higher volumes of components cost effectively. This may require the development of new specialist facilities.

These manufacturing facilities may be coastal or inland. Key requirements for the development of these facilities are access to a suitable site and easy access for transport (road, rail or water) with the capacity for this transport to handle the largest components manufactured at the facility.

Whilst site and project specific, a drag-embedded anchor used for a 20MW turbine is expected to be around 40-50 tonnes and clump weights, if used, in the region of 10 tonnes each.

4.4.8 Mooring Marshalling, Assembly, Integration and Load Out Facility

Mooring systems comprise of multiple different components which may include chain, synthetic rope, shackles, load deduction devices, anchors and clump weights. For floating offshore wind projects, the scale (size, weight, volume) of these components is significant and as such appropriate infrastructure is required to marshal, assemble and load out these components. It is typical for some of these components to be assembled at the load out facility, whilst others are assembled on the vessel just prior to installation.

These facilities require to be coastal or on large rivers with direct access to the sea. Key requirements for the development of these facilities are access to a suitably large site (for component storage, laydown and assembly), appropriate specification of quayside and direct access to the sea for the transport of mooring systems direct to the project site.

4.4.9 Dynamic Cable Manufacturing

Dynamic cable manufacturing is an industrialised process with facilities in existence across the globe, serving a global market of offshore energies industries. Floating offshore wind has a number of unique requirements with respect to the specification of a dynamic cable manufacturing facility but it is envisaged these requirements can be met through the development of existing facilities rather than a requirement to create new facilities (dedicated to dynamic cables). However, the scale of demand from floating offshore wind projects will present a significant capacity challenge for the existing dynamic cable manufacturing supply chain.

Dynamic cable manufacturing facilities may be coastal or inland. Key requirements for the development of these facilities are access to a suitably large site and easy access for transport (road, rail or water) with the capacity for this transport to handle the largest (spooled) cable lengths manufactured at the facility.

4.4.10 Dynamic Cable System Component Manufacturing

Dynamic cable system component manufacturing is an industrialised process albeit with most manufacturing facilities operating in a “batch manufacturing” rather than serial production mode. In addition, there is a range of dynamic cable system components with most being supplied from different specialist facilities. Examples include cable protection systems, bend stiffeners, buoyancy modules, dry and wet mate connectors etc. Floating wind may require a number of specialist components, the majority of which are likely to be manufactured at existing facilities. In addition, existing “batch manufacturing” approaches are likely to require development to deliver higher volumes of components cost effectively. This may require the development of new specialist facilities.

These manufacturing facilities may be coastal or inland. Key requirements for the development of these facilities are access to a suitable site and easy access for transport (road, rail or water) with the capacity for this transport to handle the largest components manufactured at the facility.

4.4.11 Dynamic Cable System Marshalling, Assembly, Integration and Load Out Facility

Dynamic cabling systems comprise of multiple different components which may include cable, connectors, bend restrictors, cable protection systems, buoyancy modules and clump weights. For floating offshore wind projects, the scale (size, weight, volume) of these components is significant and as such appropriate infrastructure is required to marshal, assemble and load out these components. It is typical for some of these components to be assembled at the load out facility, whilst others are assembled on the vessel just prior to installation.

These facilities require to be coastal or on large rivers with direct access to the sea. Key requirements for the development of these facilities are access to a suitably large site (for component storage, laydown and assembly), appropriate specification of quayside and direct access to the sea for the transport of mooring systems direct to the project site. Whilst this facility is described in this report as a separate facility, it is often co-located with the cable manufacturing facility itself (see Table 8).

4.4.12 Operations and Maintenance Facilities

To date floating offshore wind farms have been deployed close to shore and as such routine operations and maintenance activities have been performed utilising Crew Transfer Vessels (CTVs). Large scale floating offshore wind farms will be much farther from shore and mostly utilise SOVs for routine O&M activities. These SOVs will need to return to an O&M base every few weeks to change staff, replenish stores and supplies etc. These bases will be in the same region as the floating offshore wind farm, albeit the proximity to the wind farm site is less significant given the less frequent number of journeys between the base and the project site. These facilities will be coastal facilities with good transportation links, and likely develop around a number of hubs within each region.

At this stage in the industry's development there are very few vessels in existence which can cost effectively complete a major component exchange operation for a large floating offshore wind turbine. As such, plans for this operation generally and provisionally assume the entire FOWT and substructure would be towed to an appropriate port and / or sheltered water facility for the work to be completed there.

4.4.13 Decommissioning Facilities

Decommissioning facilities for floating offshore wind farms are provisional assumed to be the same facilities which are used for FOWT and substructure marshalling, assembly and integration. However, this may not be the case and it is likely that any facilities undertaking decommissioning activities would need appropriate licences for this activity.

4.5 Impact of Key Infrastructure on LCOE and GVA

Based on the assessment of the project construction, operation, maintenance and decommissioning activities a number of defined infrastructure requirements were identified. These are summarised below alongside a qualitative assessment of their potential impact on LCOE and UK GVA.

Facility / Infrastructure	Synergies Through Co-location	Impact of Proximity to Project Site on LCOE	Potential Impact on UK GVA[13]
Steel substructure component fabrication facility		M	H
Concrete substructure construction facility (may be supplied with pre-cast elements from elsewhere)		H	H
Steel substructure assembly facility		H	H
FOWT marshalling, assembly, integration and load out facility		H	H
Chain manufacturing facility		L	L
Synthetic rope manufacturing facility		L	M
Mooring component manufacturing facility		L	M
Mooring marshalling, assembly, integration and load out facility		M	M
Dynamic cable manufacturing facility		L	M
Dynamic cable component manufacturing facility		L	M
Dynamic cable system marshalling, assembly, integration and load out facility		M	M
Operations, maintenance and minor repair support facility		H	H
Major component exchange facility (and / or sheltered water facility)		H	M
Decommissioning facility		M	M

Table 8: Impact of Key Infrastructure on LCOE and GVA

H = High, M = Moderate, L = Low, Full line = synergy, Dashed line = limited synergy, No line = no notable synergy

4.5.1 Co-location Synergies

The facilities above fall into two broad categories – manufacturing facilities and port facilities. In certain cases it is beneficial for a manufacturing facility to be co-located with an appropriate port facility to allow cost effective onward transportation of goods and to create synergies in operations, expertise, research, development etc. These synergies are shown using arrows in the table above.

Typically, wind turbine blade, nacelle and tower facilities are located in coastal locations with direct access to a quayside. The same is true for monopile manufacturing facilities and jacket foundation fabrication yards. This is to reduce the cost of onward transportation of the components which is most cost effectively done by boat in batches. In addition, in the vast majority of cases the components could not physically be transported by road or rail due to height, width and weight restrictions.

[13] This considers both the absolute impact and relative impact – i.e. consideration of the impact which higher value manufacturing activities have on UK GVA.

In certain cases these manufacturing facilities are located next to large marshalling and assembly facilities. This can deliver cost and operational benefits, where the components manufactured are being supplied to projects in proximity to the co-located marshalling and assembly facility. However, for a manufacturing facility to be sustainable, it will typically have to supply projects over a much larger area, including projects using marshalling and assembly facilities closer to these project locations. As such, the co-location synergies of manufacturing and marshalling and assembly tend to be driven by other factors such as commercial and land ownership arrangements.

4.6 Infrastructure Capability

The infrastructure required to support floating offshore wind projects will only be sustainable if it is able to support and service a range of other offshore industries including the ongoing build out of deployment of fixed bottom wind, Oil and Gas (O&G) servicing and decommissioning, onshore and offshore hydrogen production and transportation infrastructure construction and servicing, carbon capture and storage (CCS), cruises, large scale materials handling, import and export etc. Ensuring infrastructure developed is able to support a range of offshore industries will reduce investment risk and cost, increase facility utilisation and hence reduce costs for those utilising these facilities.

Fixed and floating wind manufacturing, marshalling and assembly activities typically require larger laydown areas within ports than other industries, in addition as turbine sizes increase, these are driving a requirement for increased quayside bearing capacities to accommodate heavy lift activities which exceed the requirements of most other sectors. As a result, infrastructure developed to support fixed and floating wind will have broad applicability across other sectors.

4.6.1 Synergies with Other Sectors

The following table outlines some of the synergies key floating offshore wind related infrastructure will have with other sectors.

Facility / Infrastructure	Synergies With Other Sectors
Steel substructure component fabrication facility	Steel floating wind substructures will need to be assembled from component parts. These parts will need to be manufactured at facilities in markets across the globe. As such it is likely that the design of these components will be strongly influenced by the availability of facilities which manufacture relevant components such as monopile foundations, turbine towers, jacket foundations and secondary steel components for marine applications.
Concrete substructure construction facility	Concrete substructures will be manufactured and assembled at large facilities. However, these facilities will have the potential to manufacture large concrete structures for a range of other industries including bridge building, nuclear, port and harbour construction, carbon capture and storage and other marine applications.
Steel substructure assembly facility	These facilities will be large multipurpose marshalling and assembly facilities capable supporting a wide range of offshore industries including fixed bottom wind, oil and gas operations maintenance and decommissioning, offshore hydrogen production and specialist large scale good import / export.
FOWT marshalling, assembly, integration and load out facility	

Table 9: Synergies with Other Sectors

4.6.2 Design for Manufacture and Assembly (DfMA)

The ongoing optimisation and validation of substructure design shall be critical to the success of the floating offshore wind industry and as such the design of floating offshore wind turbine substructures is evolving rapidly. Designs are evolving through the technology readiness levels and early stages of industrialisation. Critical to the successful industrialisation of floating offshore wind substructures is a focus on Designing for Manufacture and Assembly (DfMA) – which is inevitably less of a focus with prototype, demonstrator scale projects.

DfMA is the process of designing substructures so they can be manufactured and assembled cost effectively at scale (unit size and volume of units). This process includes an assessment of the state of the art of large-scale manufacturing supply chain capability, port infrastructure, marshalling and assembly facilities, heavy lift vessels and cranes and other key equipment to establish design criteria (and associated limitations) associated with manufacturing and assembly and how these will evolve in the short and medium term. These criteria are then balanced against other design criteria and reviewed in the context of the ongoing development of the industry.

This process is the same as that employed by the FOWT OEMs to ensure the next generation of FOWTs are cost effective, practical and safe to install and maintain in key markets across the globe.

5 EXISTING INFRASTRUCTURE ASSESSMENT

As outlined in the previous sections there is a range of infrastructure / facilities which are required to deliver a large scale floating offshore wind project. Whilst there is an opportunity to develop and / or operate all these facilities within the UK, a number of these facilities are particularly important with respect to the cost-effective delivery of floating offshore wind projects. These facilities are shown in the table below. For purposes of this summary report these facilities will be focused on specifically.

Impact on LCOE and GVA	Definition	Infrastructure
High	This infrastructure is critical to the cost-effective deployment of floating offshore wind within a given market and, in most cases, within a specific region within that market. The absence of this infrastructure is likely to lead to increased project costs and may impact the commercial viability of projects, resulting in some projects not being constructed. Definition below also valid for this infrastructure.	Steel substructure component fabrication facility
		Concrete substructure construction facility
		Steel substructure assembly facility
		FOWT marshalling, assembly and integration facility
		Operations, maintenance and minor repair support facility
		Major component exchange facility (and / or sheltered water facility)
Moderate / Low	This infrastructure, under the management of a competitive supply chain organisation, has the potential to have a positive impact on project costs within a market as well as a significant impact on GVA created within that market.	Mooring marshalling, assembly, integration and load out facility
		Dynamic cable system marshalling, assembly, integration and load out facility
		Decommissioning facility

Table 10: Critical and Key Infrastructure for Floating Offshore Wind Projects

In order to assess and determine the potential development requirements associated with the infrastructure outlined above, we need to compare the potential demand for the capacity provided by this infrastructure with the existing capacity in the UK.

5.1 Existing Infrastructure Assessment Methodology

An assessment of existing UK infrastructure was performed using a Multi-Criteria Analysis (MCA) for each of the applications shown in Table 10. The following sections describe this process and outcomes.

5.1.1 Assessment Process

A staged approach was taken to assess the current status of the UK infrastructure with respect to the applications outline in Table 10. The first stage was to draw together a long list of relevant port facilities in the UK. A total of 78 facilities were included in this "long" list. For each of the applications outlined in Table 10, a set of "hard" pass or fail criteria were outlined. These criteria were different for the different applications. These criteria were applied to all facilities to produce a list of facilities to include in the MCA.

The MCA then employed a range of "soft" criteria which were assessed. For each criteria a scale and weighting was applied. These were different for the different applications. Each facility on the list for analysis was then scored based on these criteria to produce a ranked list of facilities for each application. A selection of these were then included in a short list for further analysis.

Figure 6: MCA Process

5.1.2 Pass Fail Criteria

The "hard" criteria applied to each facility were based on the factors in Table 11.

Pass / Fail Criteria
Water Depth at Entrance (m below chart datum)
Navigational Entrance Width

Table 11: Hard Criteria Used in the MCA

5.1.3 Multi-Criteria Analysis (MCA)

An extensive MCA was then completed to assess the existing infrastructure in the UK and its suitability and capacity to support large scale floating offshore wind projects. For the applications identified in Table 10 the following criteria were considered and scored for a range of facilities across the UK.

Location, Transport, Work Force and Supply Chain Criteria	Facility Specification Criteria
Proximity to Population	Land Suitability
Road Access	Wet Storage Suitability
Rail Access	Air Draught
Airport Access	Total Quay Length
Proximity of Supply Chain	Total Quay Depth
Existing Offshore Wind Activity	Quay Bearing Capacity
Proximity to FOW Potential Zones	Navigation Approach Width
	Navigation Approach Depth
	Dry Dock Dimensions

Table 12: Soft Criteria Used in MCA

The outcomes of the MCA provided an excellent insight into the current status of UK infrastructure with respect to the floating offshore wind applications outlined in Table 10. It also highlighted where different applications have similar criteria and hence the same facilities would be considered a similar level of suitability for multiple applications.

5.1.4 Configuration and Utilisation of Capacity

Infrastructure capacity can be configured and combined in a number of different ways depending on the needs and scale of the project. In this context, most facilities in the UK have the potential to play a role in large scale floating offshore wind project delivery (assuming to pass the hard criteria applied for a given application). However, a much smaller proportion of the facilities have the potential to play a significant role in the cost-effective delivery of large scale floating offshore wind projects. In this context, there is merit in endeavouring to establish some guidance criteria which may be used to gauge the minimum requirements for an individual facility to play a significant role in the delivery of projects – in the context of this project this was determined to be a facility with an annual capacity of >25 units / annum or approximately 500MW of installed capacity. These are discussed further in Section 5.2.6.

There is the potential to increase this capacity by increasing the size of the facilities themselves and / or utilisation of multiple facilities for the same function (for example where a number of smaller facilities already exist). Utilising multiple facilities for the same function is likely to be relatively easy and cost effective for certain activities, specifically those which have low / no mobilisation costs like steel substructure component manufacture, cable manufacture etc. However, the activities with significant mobilisation costs, for example the steel-substructure assembly activity, it is less likely to be cost effective to split these activities across multiple facilities.

5.1.5 Factoring Capacity and Utilisation

The guidance criteria and associated capacities developed assume full utilisation of the facility for the purposes of floating offshore wind project delivery. In certain cases it won't be commercially or practically feasible to do this for the infrastructure owner. This is particularly true for the port infrastructure. As such when assessing the existing and planned UK infrastructure capacities, these have been factored to account for this. In most cases the utilisation was reduced to between 60-80%, with the majority of the capacity dedicated to floating offshore wind project delivery. These utilisations were established through dialogue with the relevant infrastructure owners.

5.2 Summary of Existing UK Infrastructure

The sections below provide a brief overview of the regional status of existing infrastructure in the UK. Guidance and context is provided at a regional level only for the purposes of this summary report but is based on the detailed assessment of a number of relevant facilities in each region.

5.2.1 Scotland

Scotland has been supporting major offshore energy activities in the North Sea since the 1970s. This has led to the development of significant port infrastructure and offshore energy supply capability in Scotland, predominantly on or close to the east coast. Particular hubs include Leith / Rosyth, Dundee, Aberdeenshire coast and the Cromarty and Moray Firths. On the west coast and outer isles, a number of facilities have also been developed, for example Arnish and Kishorn. The Clyde Estuary also has a number of facilities associated with ship building, defence and aggregate / minerals handling.

Scotland has a number of existing offshore wind farms with a strong pipeline of further projects in various stages of development. The vast majority of these are on the east coast with clusters in the outer Firth of Forth / Firth of Tay and outer Moray Firth (see Figure 4).

Scotland still supports a significant level of oil and gas activity in the central North Sea, Northern North Sea and West of Shetland. This is typically supported from facilities in Aberdeen, Cromarty Firth and Lerwick. Scotland also has the potential to host a significant proportion of oil and gas decommissioning activities over the coming decades.

5.2.2 Celtic Sea

The Celtic Sea is generally considered to incorporate the area of the UK's Exclusive Economic Zone (EEZ) which lies south west of south Wales (south of the St George's channel), north west and south west of Cornwall. The area lies exclusively within the shipping forecast areas of Lundy and Plymouth and in the eastern halves of Fastnet and Sole.

The region has developed coastal infrastructure primarily for the purposes of importing and exporting aggregates and minerals, with some other infrastructure developed to support various industrial activities and the import of liquid natural gas. Significant infrastructure exists around Port Talbot, Milford Haven and Bristol Port and further north in the Irish Sea at Belfast and Liverpool. Cornwall has a strong maritime heritage and has developed a large number of smaller facilities which support leisure and commercial marine activities including boat building.

To date the Celtic Sea has seen very limited offshore wind development activity. With a number of projects in the region being granted leases but not progressing beyond this stage.

5.2.3 North East England

The North East of England has significant port and manufacturing infrastructure around Newcastle, Middlesbrough and the Humber Estuary. Most of the facilities have been in place in some form for more than 100 years. However, in the last couple of decades significant redevelopment of a number of facilities has taken place to repurpose or expand them. This redevelopment is ongoing – for example, in Grimsby docks which is being developed into a servicing hub for offshore wind projects in the southern North Sea.

The infrastructure services oil and gas activities in the Central North Sea, import and export of goods and materials to Europe, various other industrial and chemical processing activities alongside offshore wind turbine component manufacture, construction, operations and maintenance.

The North East of England continues to service a range of industries from its coastal port and industrial facilities. Offshore wind is a major industry in the region with a strong pipeline of projects in development – including the world's largest offshore wind farm in development Dogger Bank.

5.2.4 Green Field Development

The MCA included an assessment of the potential to develop a "green field" facility. This was done to determine the potential timescales and costs of developing a facility in the UK "from scratch" – albeit at a location which has inherent characteristics which lend themselves to such a development. It was clear from the assessment that the timescales, costs and environmental impact of such a development were very significant. As such, the development requirements considered below all relate to the development of existing facilities rather than the creation of new facilities.

5.2.5 Summary of MCA Outcomes

A number of observations on the outcomes from the MCA analysis are made below. It should be noted that the MCA was performed with a focus on port infrastructure, as such where manufacturing facilities are referenced below, the MCA simply considered the potential for port infrastructure to host these facilities.

Infrastructure	Comments on MCA Outcomes
Concrete substructure construction facility	No existing facility in the UK was identified as meeting all the requirements. A small number of facilities were identified as having the potential for development to meet these requirements, with a at least one facility in each of the three regions having this potential.
Steel substructure assembly facility	No existing facility in the UK was identified as meeting all the requirements. In Scotland and the North East of England a small number of facilities exist which have the potential for development to meet these requirements.
FOWT marshalling, assembly and integration facility	No existing facility in the UK was identified as meeting all the requirements. In Scotland and the North East of England a small number of facilities exist which have the potential for development to meet these requirements.
Operations, maintenance, minor repair facility	There are a large number of suitable facilities for this application spread across the UK. Each of the three regions of interest had multiple facilities capable of fulfilling this role.
Major component exchange facility (and / or sheltered water facility)	This application has similar requirements to FOWT marshalling, assembly and integration facility and hence the same comments apply here. However, the scale of the major repair activities is likely to be considerably smaller and hence only use part of this facility.
Steel substructure component fabrication facility	No existing facility in the UK was identified as meeting all the requirements. However, a number of facilities were identified as having the potential to develop this capability. With multiple facilities in Scotland and North East England being identified, and at least one in the Celtic Sea region.
Mooring marshalling, assembly, integration and load out facility	A small number of facilities across the UK were identified which met the requirements, mainly located within Scotland and North East England. With a much larger number being identified as having the potential for development to meet these requirements.
Dynamic cable system marshalling, assembly, integration and load out facility	A small number of facilities across the UK were identified which met the requirements. With a much larger number being identified as having the potential for development to meet these requirements.
Decommissioning facility	There is significant uncertainty regarding the requirements of FOW with respect to decommissioning. For the purposes of this study the requirements were assumed to be the same as the major component exchange facility and hence the same comments apply here.

Table 13: MCA Outcomes Summary

For the purposes of this summary report, only the applications where no suitable facilities have been identified shall be discussed further. It should be noted that for other facilities – such as dynamic cable manufacture – additional capacity in the UK supply chain would be beneficial but these facilities should be able to establish in / around existing infrastructure with only moderate infrastructure development requirements.

5.2.6 Summary of Key Facility Capacity and Specification Criteria

An extensive range of criteria were established to assess the suitability of infrastructure for the potential applications of interest. For the critical infrastructure identified, key metrics included the physical size (area) of the area with direct access to the quayside and its ability to accommodate large floating offshore wind technology at the quayside (quayside length, draft and bearing capacity).

Extensive stakeholder engagement, engineering analysis and assessment was completed to ascertain appropriate criteria for a range of key metrics including productive site area, quayside draft, length and bear capacity. This suggested a range of values for each of the key metrics with significant sensitivity to the design of the substructure and requirement / proposal to use launch / assembly aids.

Despite these uncertainties it was considered useful to determine a number of key criteria that if satisfied at a particular facility would mean that in all likelihood would have the potential to support large scale floating offshore wind related activity with the required levels of operational efficiency (in the context of similar international facilities).

It should be noted that these criteria are only a guide. However, they help to clearly articulate the scale of the facilities which are most suited to supporting floating offshore wind project delivery.

Infrastructure	Capacity[14]	Productive Site Area	Quayside Draft[15]	Main Quay Length[16]
Concrete substructure construction facility	>25 units / annum	20 ha manufacturing, 10 ha assembly, plus 5-10 ha wet storage	10-14m	>500m
Steel substructure assembly facility	>25 units / annum	10 ha assembly, plus 5-10 ha wet storage	8-12m	>500m
FOWT marshalling, assembly and integration facility	>25 units / annum	20 ha marshalling and assembly, plus 5-10 ha wet storage	10-15m	>500m
Steel substructure component fabrication facility	>25 units / annum	20 ha manufacturing	5-8m	>200m

Table 14: Guide to Critical Infrastructure Requirements

To put the requirements above in the context, the table below summarises key characteristics of relevant existing European facilities. Appendix 1 includes a number of schematics which put these site areas in context.

Infrastructure Owner	Facility	Main Quay Length (m)	Main Quay Draft (m)	Yard area (ha) – indicative
Haizea Wind Group	Port of Bilbao, Spain	450	16	18
Windar	Port of Aviles, Spain (Asturias)	985	10	19
GSG Towers Sp. Z o.o.	Port of Gdansk, Poland	410	8,5	12
Gestamp Renewables	Port of Seville, Spain	120	5	6
ASM	Port of Averio	200	10	25
Ambau / Titan Wind Energy	Cuxhaven, Germany	200	10.6	32
Titan Wind Energy and Welcon	Port of Esbjerg, Denmark	500	9.4	112
Navantia	Port of Ferrol	395	8	38

Table 15: Representative International Infrastructure

14 Capacity for manufacture was based on year-round manufacturing activity. Capacity for marshalling and assembly was based on assembly and deployment activities over a 28-week period (spring-summer-autumn).
15 A range of assembly and installation aids exist and are in development which have the potential to reduce this requirement. However, their availability, applicability and project cost impact are highly uncertain and so there is a strong benefit to develop facilities which are not reliant on such aids.
16 These quay lengths are based on requiring a quay to be able to load in / out components from a large vessel (200m plus), and where assembly activities are also taking place, accommodate two substructures at the quayside (2x100m), with appropriate separation.

5.3 Infrastructure Development Requirements

The UK's infrastructure development requirements are directly linked to the future offshore wind deployment scenarios in the UK. Other factors will influence the specification, timing and scale of any infrastructure development, such as the demand from other sectors, but in all cases the role of offshore wind deployment scenarios is the most significant in terms of scale and also has the most significant requirements with respect to laydown area and quayside bearing capacity.

The following sections provide a high-level overview of the development requirements across the regions in the context of a range of future offshore wind deployment scenarios. The information provided is intended to act as a guide and link the development requirements, to the investment required to deliver these developments, to the capacity required to cost effectively deliver a range of future offshore wind deployment scenarios in the UK. Whilst the information provided is provided at a regional level, it is based on a range of facility specific development plans and hence is considered to give a good guide as to the levels of investment which may be required.

5.3.1 Scotland

The port facilities which could host manufacturing and / or marshalling and assembly were located mainly in Scotland. This is a result of Scotland having a larger number of facilities with deeper port navigation, quays, larger development land potential, as well as good possible sheltered anchorage for wet storage.

Infrastructure Application	Number of Facilities	Potential Capacity	Infrastructure Development Cost	Development Timescales
Concrete substructure construction facility	Two facilities identified and assessed	36 units / annum between both facilities	£300m between two facilities, port infrastructure only	Development activity required, full capacity potential by 2030
Steel substructure component fabrication facility and co-located steel substructure assembly facility	Two facilities identified and assessed	45 units / annum between both facilities	£200m between two facilities, port infrastructure only, manufacturing facilities themselves estimated at £150-250m each	Development activity required, capacity available between 2025 and 2027
FOWT marshalling, assembly and integration facility	Multiple facilities identified, three assessed in detail	142 units / annum	£400-500m across three facilities, port infrastructure only	Development activity required, capacity available between 2025 and 2027
All	**All**	**142 units or 2.5GW**	**£900-1,000m, port infrastructure only**	**2025-2030**

Table 16: Strategic Infrastructure Investment Requirements – Scotland

Based on the information provided in Table 16, there are a small number of potential facilities in Scotland which could be developed to support the delivery of a strong pipeline of projects from 2025. A cumulative investment of around £1bn (excluding manufacturing facilities) has the potential to unlock the capability and capacity to manufacture and assemble both steel (from 2025-2027) and concrete (by 2030) substructures in Scotland, in addition to ensuring FOWT marshalling, assembly and integration can happen in Scotland (from 2025). This investment would enable the capacity to deliver approximately 140 units from Scotland, with a substantial proportion of the substructures also being manufactured and assembled in Scotland (36 units for concrete, 45 for steel). In the nearer term, this equates to around 2.5GW of installed capacity annually. If 100% Scottish content was desired, a maximum capacity of 1.4GW (or 81 units) annually could be deployed (assuming split of steel and concrete foundations). This would be delivered from a total of six port facilities (one facility hosting both steel substructure component manufacturing and FOWT and substructure marshalling and assembly).

5.3.2 Celtic Sea

A small number of facilities in the Celtic Sea region were identified as having potential to support substructure manufacturing and / or assembly, and FOWT marshalling, assembly and integration activities.

Infrastructure Application	Number of Facilities	Potential Capacity	Development Cost	Development Timescales
Concrete substructure construction facility	Two facilities were assessed, one existing and one "green field"	30 units / annum, one facility only, includes marshalling and assembly	£700m (includes marshalling, assembly and integration facility), one facility only, port infrastructure only	Development activity required, phased development assumed with increasing capacity available between 2025-2030.
Steel substructure component fabrication facility and co-located steel substructure assembly facility	Two facilities were assessed, one existing and one "green field"	25 units / annum, one facility only	£400-600m (includes marshalling, assembly and integration facility), one facility only, port infrastructure only, manufacturing facilities themselves estimated at £150-250m each	Development activity required, phased development assumed with increasing capacity available between 2025-2030.
FOWT marshalling, assembly and integration facility	One facility and co-located with steel substructure assembly facility	40 units / annum, steel substructure facility only	Included in the figure presented the boxes above.	Included in the above.
All	**All**	**40 units or 700MW**	**£400-600m (excluding "green field")**	**2025-2030**

Table 17: Strategic Infrastructure Investment Requirements – Celtic Sea

Based on the information provided in Table 17, there is a single existing facility in the Celtic Sea region which could be developed to support the delivery of a strong pipeline of projects from within the Celtic Sea. A cumulative investment of between £400-600m has the potential to unlock the capability and capacity to manufacture and assemble steel or concrete substructures in the Celtic Sea, in addition to ensuring FOWT marshalling, assembly and integration. This investment would enable the capacity to deliver up to 40 units, with a substantial proportion of the substructures also being manufactured and assembled in the region (30 units for concrete, 25 for steel). In the nearer term, this equates to around 700MW of installed capacity annually.

Additional capacity could be developed in the form of a "green field" development, but this is estimated to require very significant investment (£700m) and take an extended period to develop (>10 years) and hence is not considered viable unless a significant pipeline of floating offshore wind projects are developed in the Celtic Sea (a pipeline requiring more than say 1GW of deployment annually). The investment and capacities above, and findings further in this report, assume this development is not progressed.

5.3.3 North East England

A number of facilities in the North East of England were identified as having significant potential to support substructure manufacturing and / or assembly, and FOWT marshalling, assembly and integration activities.

Infrastructure Application	Current Status	Potential Capacity	Development Cost	Development Timescales
Concrete substructure construction facility	One facility was assessed but excluded detailed assessment of development costs	20 units / annum	£100-200m, port infrastructure only	Development activity required, full capacity potential by 2027
Steel substructure component fabrication facility and co-located steel substructure assembly facility	Two facilities were assessed, but one did not include detailed assessment of development costs	39 units / annum	£600-700m, port infrastructure only, includes marshalling and assembly for one facility, manufacturing facilities themselves estimated at £150-250m each	Development activity required, full capacity potential by 2027
FOWT marshalling, assembly and integration facility	Two facilities were assessed, but one did not include detailed assessment of development costs	66 units / annum	£50m, port infrastructure only, costs for marshalling and assembly at other facility included in costs above	Development activity required, capacity available between 2025 and 2027
All	**All**	**66 units or 1.2GW**	**£750-950m**	**2025-2027**

Table 18: Strategic Infrastructure Investment Requirements – North East England

Based on the information provided in Table 18, there are a small number of potential facilities in North East England which could be developed to support the delivery of a strong pipeline of projects from North East England. A cumulative investment of between £750-950m has the potential to unlock the capability and capacity to manufacture and assembly both steel and concrete substructures in the region, in addition to ensuring FOWT marshalling, assembly and integration can happen in North East England. This investment would enable the capacity to deliver up to 66 units from North East England, with a substantial proportion of the substructures also being manufactured and assembled in the region (20 units for concrete, 39 for steel). This equates to around 1.2GW of installed capacity annually.

5.3.4 Summary of Infrastructure Development Requirements

The sections above provide a guide as to the potential development requirements across the three regions of interest. It can clearly be seen that the development requirements across the three regions are different, with each starting from a different baseline. In addition, even with the above developments progressed, each region is likely to have some form of upper limit to annual deployment capacity. Additional capacity could be developed, albeit this is likely to require an increased cost per unit deployed.

6 INFRASTRUCTURE INVESTMENT REQUIREMENTS

The infrastructure assessed as part of this project can be categorised into two broad categories – manufacturing facilities and port infrastructure facilities. These two broad categories of infrastructure have distinct business models and in turn present different business cases for investment.

6.1 Infrastructure Owner / Operator Business Models

The table below summaries the different business models. Each of these different business models is associated with different revenue and cost profiles. In addition, the medium- and long-term visibility of revenue is different for the different business models.

Business Type	Role	Revenue Streams	Revenue Visibility	Market
Port Infrastructure Owner	Owner of the physical port site and quayside infrastructure / asset. May also operate the port.	Rent / revenue share paid by port operator (for marshalling), or long term rental of manufacturing facilities. Also items below if operating port.	Long term (10 year) for manufacturing facility leases and shorter term (1-2 years) for port operator rent / revenue share.	Limited to port users. Sensitive to medium- and long-term regional demand.
Statutory Harbour Authority (not always the same as the infrastructure owner)	Responsible for managing and maintaining the navigational waterway and harbour	Port dues for vessel and cargo fees (if also the Statutory Harbour Authority)	Visibility is short term (0-1 year) for port vessel and cargo handling dues.	Limited to local port movements generated by the activity within the harbour.
Port Infrastructure Operator	Operator of the port site and quayside. May be same as the port owner.	Vessel and quayside support services provided within port, short term rental of port laydown areas.	Short term (0-1 year) for support services, 1-2 years for short term rental of laydown areas.	Limited to port users. Highly sensitive to short- and medium-term regional demand.
Manufacturing Facility Operator	Operator of the manufacturing facility located within a port site.	Sale of manufactured items.	Medium term (1-5 years) sales pipeline including framework agreements.	Regional, national. Sensitive to national demand in the medium term.

Table 19: Infrastructure Owner and Operator Business Models

6.1.1 Revenue and Cost Profiles

Port infrastructure owners typically have relatively stable cost profiles linked to the ongoing operations and maintenance of the port facilities, plus their requirement to service any debt. The revenue profiles for port owners depends on the approach they have taken to operating the port infrastructure itself. Typically, long term leasing or revenue sharing arrangements are entered into for both port operation and the use of manufacturing facilities within the site. These are long term leases (>10 year) and hence provide long term visibility of revenue.

Port infrastructure operators have a more variable cost profile as a proportion of this is linked to the utilisation of the port infrastructure and associated charging mechanisms, with the remainder linked to rental payments and servicing any debt. Revenue profiles are typically also linked to utilisation of the port infrastructure and associated charging mechanisms, meaning the variability in these profiles is correlated. Visibility of both variable cost and revenue profiles is generally only short term (0-2 years) and highly sensitive to relevant regional market activity.

Manufacturing facility operators typically have relatively stable cost profiles linked to the ongoing operation of the facility, including both fixed and variable costs. Most facilities are operated in a serial production mode allowing variable costs to be controlled. These facilities typically serve a wider regional or national market and hence revenue profiles are less sensitive to relevant regional market activity.

The revenue and cost models outlined above are key to understanding the different options available with respect to infrastructure development funding, as well as the potential limit to the scale of this development funding through conventional means. There is a wide variety of development funding available with different funding structures utilised for different investment propositions. In addition, infrastructure owners will have quite different requirements in terms of risk appetite, returns on investment etc, depending on the sort of organisation they are. Work commissioned by Scottish Enterprise provides a useful overview of the key potential investment options for port infrastructure[17] and presents some of the existing schemes in more detail.

6.2 Infrastructure Ownership

The section below outlines the main ownership structures for port infrastructure.

Ownership Type	Ownership and Governance	Profit Sharing	Borrowing Options	Typical Investment Return Period
Trust Ports	Board of Trustees	Retained	Private loans, private equity through JV, public sector loans including development agency / bank loans	25-50 years
Private Ports	Board, on behalf of shareholders	Dividends to shareholders	Corporate finance, private loans, private equity through JV, public sector loans including development agency / bank loans	15-25 years
Local Authority Owned	Board, typically local councilors	Distributed within local authority	Private loans (subject to certain criteria being met), public sector loans including development agency / bank loans	10-15 years, albeit project specific

Table 20: Infrastructure Ownership Models

6.2.1 Trust Ports

Trust Ports are independent ports which are governed by their own local policy and are run by boards, which have the authority to manage the assets of the trust on behalf of stakeholders. Trust Ports function in a commercial manner; that is, there is no direct public support. Despite this, there are no beneficial shareholders and 100 percent of profits are reinvested in the port. Trust Ports acting as Statutory Harbour Authorities, source additional income from the conservancy charges for pilotage and vessel dues management of the waterways. Trust Ports can utilise a variety of funding sources, which could include private sector corporate borrowing, retained earnings and cash, receiving equity from a joint venture and support from the public sector in the form of grants or loans. Trust Ports operate with a stakeholder inclusive business model; that is, as part of their investment process they are more able to incorporate wider economic benefits as well as financial returns.

[17] Port Investment Models for Offshore Wind, QMPF, 2021

6.2.2 Private Ports

Over the past 30 years there has been a move to a private ownership model in the UK (particularly for larger ports) which operate as private companies and may be part of larger portfolios due to synergistic benefits. Private Ports often own the land on which they operate. These ports are owned by shareholders and will operate to produce shareholder value. Private Ports may be less restricted than Trust Ports for sources of financing as they may have larger balance sheets, more diversified operations, and the backing of large institutional shareholders may result in the port being perceived as stronger and more favourable by lenders. This funding could be in the form of private debt or equity for projects, and corporate financing. Where innovative solutions are being tested, or new technologies implemented, or activities positively impact the surrounding area, investment may be sought from public sources to support the initiatives.

6.2.3 Local Authority Owned (or Municipal) Ports

Local Authority Owned (or Municipal) Ports are ports which are owned by the local government and are usually managed through a board of elected local councillors and regulations. Local authorities may have borrowing powers to lend to harbour authorities, which can be located either wholly or partially in the local authority area. National government regulations often set out how local authorities can borrow money. These regulations may allow local authorities to access public sector funding in a variety of forms which could be at lower than market rates for ports, for instance, the Public Works Loan Board (PWLB). Therefore, these funding sources can be used to finance port infrastructure where either local or national government criteria is met. As local or national authorities may accrue wider economic benefits of port investments, they may look wider than traditional financial metrics to impact on wider stakeholders, such as, employment when making an investment decision.

6.3 Infrastructure Development Funding Options

The following sections provide an overview of the main public and private financing options for port infrastructure development.

6.3.1 Public Sector Overview

The public sector, typically Government or its agencies, plays a key role in supporting the development of strategically important national infrastructure. This includes infrastructure such as roads, railways, energy transmission systems, energy generation capacity, hospitals, schools etc. A myriad of mechanisms and schemes exist but these can typically be grouped into a number of main categories which are described below.

6.3.2 Public Sector Debt

The Government can borrow at a lower rate than the private sector, due to the low likelihood of default. This can allow UK infrastructure projects to benefit from the national government's creditworthiness, and thus more advantageous terms. The UK government has multiple different mechanisms / facilities that allow infrastructure projects to access debt on appropriate terms. An example of this model is the loan provided to Aberdeen Harbour by the Scottish National Investment Bank (SNIB).

6.3.3 Public Sector Equity

National and local authorities or development banks may choose to invest equity in an infrastructure project and / or part or full ownership of infrastructure. One of the key determinants for the use of equity is the desire to retain a level of control in the project. Similar to private sector equity, public sector equity financing involves selling a stake in a business in return for a cash investment. Additionally, the public sector could choose to provide land or other resources as equity. Public sector equity financing does not include a repayment obligation. Therefore, the public sector bears risk associated with the performance of the project. An example of this model is the ownership stake Scottish Enterprise have in Energy Park Fife.

6.3.4 Public Sector Grants

Where a project is of strategic importance or where there is a market failure, the public sector may provide grant funding to support the viability of a project, bridging a gap to make the project affordable for investors. The grantor may do this because they may be able to accrue socio-economic benefits from the project or the project aligns with strategic objectives. Recent examples of this in offshore wind include the Offshore Wind Manufacturing Investment Support (OWMIS) and the Floating Offshore Wind Manufacturing Investment Support (FLOWMIS) schemes.

6.3.5 Public Sector Other

The public sector can provide alternative forms of support for a project aside from direct funding or investment. In other industries, there are schemes to provide greater certainty over revenues, such as Contract-for-Difference (CfD) for renewable energy or the Regulated Asset Base (RAB) model for new nuclear power stations. These are examples of a wider portfolio of models which Government are able to use to share, reduce and / or underwrite risk associated with major strategic infrastructure development. Such mechanisms include loan guarantees, revenue floors, revenue gap funding and specific support for certain situations such as delays.

In addition to the mechanisms above which relate to direct funding or financial support for a facility, a range of fiscal incentive schemes exist which have the potential to have a tangible impact on the business model and / or investment case for infrastructure development. A wide range of schemes exist which include designations and classifications such as innovation zones, enterprise zones and most recently Freeports (UK) and Green Freeports (Scotland).

The Freeports and Green Freeports schemes have only been developed recently but appear to have a significant impact on the business case for both port infrastructure investment and co-located manufacturing facilities, with recent Freeports in England (Teeside and Humber) being the focus of a number of manufacturing investments relevant to offshore wind.

6.3.6 Private Sector Overview

Private sector funding is capital which can be invested as equity or debt from private investors. Key stakeholders in the private sector can be broadly grouped as investors and lenders.

- Investors are looking for an attractive project with sufficient compensation for the level of risk. Investors could include infrastructure funds, private equity funds, pension funds, sovereign wealth funds or investment arms of large corporations;
- Lenders are looking for creditworthy investors or projects with a low level of risk. Lenders may include banks and institutional investors.

Lenders and investors typically take a strategic approach to their investments and will established specialist teams and funds to investment in different areas. Infrastructure investment is such an area with a global network of funds and specialist investment teams focused in this area. Whilst focused, these funds and specialist teams typically invest in a range of similar but distinct infrastructure projects to manage and mitigate risk. As such they assess the risk / reward profile for a specific infrastructure investment opportunity (such as an offshore wind port facility) with other similar infrastructure investment opportunities within that same and similar sectors. In this context, the acceptable risk / reward profile for offshore wind infrastructure investment is not set just by the absolute risk levels associated with offshore wind, rather by the relative difference in risk between these projects and other similar infrastructure projects in other sectors. These risk / reward profiles will vary over time with broader macro-economic trends.

The project engaged with the private sector investors to understand the wider drivers and opportunities associated with investment in port infrastructure relevant to offshore wind. Both private equity investors and lenders may look at the commitments from tenants and key stakeholders, in relation to value and length of contracts, ahead of investment. The level of certainty that can be provided to investors and lenders will impact the terms for funding and also the potential amount of investment that can be provided.

6.3.7 Private Debt

Private debt is money borrowed from a private institution by another party. A private debt arrangement gives the borrower permission to borrow money under a number of defined conditions, which may include term length, interest, payment profile and restrictive covenants. Covenants are conditions that lenders place on lending arrangements to limit the actions of the borrower. The covenants may define certain financial ratios are met, place a limit on debt quantum, require or prohibit activities or the inclusion of specific reserve accounts. Debt can either be invested at a corporate level into a company or for a specific project through a special purpose vehicle ('SPV').

The capacity for debt in a project will depend on the potential operating profit and certainty of revenues. The cost of debt could also impact the capacity in the project including margins and upfront fees and any conditions provided by the lender. Margins can vary significantly depending on the risk profile for a project and length of debt repayment in relation to project specific investment, leverage could also vary. Key considerations would include the creditworthiness of borrower, counterparty risk of tenant, certainty of demand, contract length and the level of existing commitments. It should be noted that in the context of port infrastructure, the financial strength and position of different port owners can vary significantly, which can have a significant impact on the scale and format of private borrowing options. An example of this model is the debt provided by Royal Bank of Scotland in the recent expansion of the Port of Cromarty Firth.

6.3.8 Private Equity

Equity financing involves selling shares in a company in return for a cash investment. Equity investors will provide funds in exchange for returns which are earned through future distributions. Unlike debt, equity financing does not carry a repayment obligation. Therefore, equity providers are earning a return on the risk associated with the performance of the company. A greater degree of equity funding may be used where risks surrounding the project are higher and may limit capacity for debt.

6.3.9 Private Other

For smaller funding requirements, there may be interest from supply chain operators such as developer to invest in the infrastructure – either in the form of debt or equity. There are a range of reasons for doing this including to support the development of strategically important infrastructure such as O&M facilities, demonstrate commitment to the use of a facility, to secure preferential rates for the use of a facility, to utilise test structures/equipment and methods for fabrication or marshalling and assembly etc. An example of this model is the debt provided by SSE Renewables and Mainstream Renewables in the proposed Nigg turbine tower factory (albeit this debt is primarily intended to support the manufacturing facility and not the enabling port infrastructure).

6.4 Key Characteristics of Offshore Wind Infrastructure Investment

To assess and identify appropriate investment models for infrastructure development it is important to understand what the investment opportunity looks like from the perspective of the potential investors and their different investment objectives and approaches and appetite for managing risk. The investment opportunity associated with the development of the port infrastructure itself is distinct from the investment opportunity associated with the development of manufacturing facilities within that facility – albeit the two may be progressed together.

The table below summarises the key characteristics of the investment profiles for port infrastructure relevant to offshore wind.

Factors	Project Assumptions	Private Investor View	Implication	Mitigation
Long Construction Phase, where no income is generated	Preliminaries and construction can take between 4 and 10 years.	Prefer shorter construction periods limiting construction risk and potentially increasing certainty over operating revenues and costs.	Potentially increased cost of funding to manage the risks.	Phased development, albeit this may increase overall costs.
Very Significant Funding Requirement	Size of initial capital expenditure, between £50-500m	Investors will have a quantity of capital that they are able to provide. Public sector investment is typically relatively modest in scale at less than £30m. Private investment may be more significant, between £30m and £300m.	There may be a need for multiple sources of financing to meet initial capital requirement.	Investors may need to seek external funding from the private and public sector.
Asset Life	The asset life of port infrastructure is long (>50 years) and is potentially longer than the project life.	Investors require assets in a sufficiently long life to earn a return on capital invested.	This may drive appetite in the market for the investment.	There may be potential for investors to consider options surrounding what to do at the end of the project life.
Predictability of Demand	The long-term demand for floating offshore wind is difficult to predict.	Investors prefer visibility of demand of 10 years of greater.	There could be a potential for increased cost of financing.	Wider stakeholders in the supply of FOW may need to take on some of the demand risk or the pipeline needs to be made more visible.
Length of Contracts	The length of contracts may be relatively short for marshalling and assembly (1-2 year). Contracts for fabrication facilities may be medium term (10 year).	Investors may prefer long-term commitments to provide more certainty for future revenues.	Lack of long-term commitments could lead to increased risk for investors and more expensive financing.	Provide certainty over long-term demand to provide assurance to investors that they will be able to replace churn.
Margins	The significant downward cost pressures within offshore wind mean margins are low, in turn limiting the margins ports can earn. In addition, ports face competition from abroad.	Investors prefer larger margins so that they can recover their initial capital invested.	The margins may not be sufficient to attract investors.	Public sector may need to provide gap funding support to crowd in private investment.
Land Ownership / Residual Value	Depending on the project structure the port infrastructure could be on land owned or leased.	Investors prefer to own land or hold a sufficiently long enough lease that they can realize value associated with project. Also enables investors to utilise land for alternative purposes if required.	If the lease is short in length the investors may struggle to realize any residual value at the end of the project life.	Project structure may need to include the option to own land or hold long-term lease, to allow investors to realize value.

Table 21: Key Characteristics of Offshore Wind Port Infrastructure Investment

The table below summarises the key characteristics of the investment profiles for manufacturing facilities relevant to offshore wind.

Factors	Project Assumptions	Private Investor View	Implication	Mitigation
Short Construction Phase, where no income is generated	Preliminaries and construction can take between 0 and 3 years.	Short construction periods limit construction risk and should reduce time to first revenues.	Ensure any key enabling construction work within the port is complete in advance of need.	Minimise construction period, ensure any key enabling construction work within the port is complete in advance of need.
Moderate or Significant Funding Requirement	Size of initial capital expenditure, between £50-200m.	Investors will have a quantity of capital that they are able to provide. Public sector investment is typically relatively modest in scale at less than £30m. Private investment may be more significant, between £30m and £300m.	Wide range of potential investors, subject to confidence in revenue and general risk-profile for the project.	Secure advance first orders for manufacture to ensure first revenues are achieved.
Asset Life	The asset life of manufacturing facility and equipment is reasonable (>10 years).	Investors likely to seek to secure full return on investment over asset life period.	This may limit length of investment payback period, although if there is sufficient forecast demand anticipated after, this could provide further comfort to investors	Ensure first contracts are secured by FID to avoid delay in first revenues. Earn sufficient margins to repay investment over asset life.
Predictability of Demand	The medium-term demand for manufactured items in market needs to be strong.	Investors prefer visibility of demand of 10 years or greater.	Strong focus on securing first orders to demonstrate market demand.	Ensure first contracts are secured by FID to demonstrate market demand.
Length of Contracts	The length of supply contracts may be relatively short (1-2 year)	Investors may prefer long-term commitments (e.g. framework contracts) to demonstrate medium term pipeline.	Lack of long-term commitments could lead to increased risk for investors and more expensive financing.	Ensure first contracts are secured by FID to demonstrate market demand. Establish framework agreements or strategic partnerships. Discuss payment mechanisms best suited to the risk in forecast revenues (potential combinations of fixed/variable payments).

Table 22: Key Characteristics of Offshore Wind Manufacturing Infrastructure Investment

6.5 Summary of Business and Investment Case Modelling and Engagement

As part of the project, a detailed business and investment case was developed for ten facilities across the UK. This assessed the costs of the development required, the timescales over which this development would happen (including the phasing of prelims and CAPEX investments), the potential structure of those investments based on the different ownership models, the likely revenue and cost profiles for the developed infrastructure and the ability for the operational facility to generate sufficient revenues in excess of costs to cover debt repayment. This included a range of different port infrastructure facilities suitable for the development of steel and concrete substructure components manufacturing facilities, substructure assembly, FOWT and substructure marshalling, assembly and integration.

It should be noted that the pricing model used for each port facility was the same. Each had the same assumed charge out rates for leasing fabrication facilities over the long term, leasing laydown area in the short term, rates of port dues. Each also had the same cost rates for facility maintenance, staff costs, insurances, dredging (where required) etc. The reality is that there will be some variability in these rates between facilities based on their location, specification and supply / demand for such facilities. However, based on engagement with ports and the national and international competitive context within which they operate, the fixed rates utilised were considered representative for the purposes of the analysis work.

The above analysis was supported by a literature review and extensive stakeholder engagement including engagement with port owners, operators, investors, supply chain and public sector stakeholders.

A number of findings are presented below.

6.5.1 Business and Investment Case – Port Facilities

- The utilisation of port facilities (out with manufacturing facilities within the port) is highly sensitive to regional market activity;
- Revenue associated with port utilisation is variable and strongly linked to port utilisation for major project activities, such as its use for marshalling and assembly of components for the construction of an offshore wind projects;
- The investment requirement for major port infrastructure development can be significant or very significant (£50-500m). This can include considerable investment even in the preliminary stages of development to develop plans, securing permissions and consents in advance of construction project financing;
- They are considered to represent relatively higher risk investment propositions where there is a lack of confidence in the medium- or long-term market demand in that region, and hence lack of confidence regarding the ability to generate sufficient and stable revenues. This increases the risk for investors, potentially increasing cost of financing and also reducing the potential for the quantum of third party debt that could potentially be introduced. Visibility of future revenues (through the contractual commitment to utilise a port) is typically only short term (<2 years in advance);
- The development and construction period is often significant, which could increase risk for investors. Providing visibility for the potential demand of the facilities and pipeline for FOW could provide confidence to investors. However longer construction periods could increase the potential cost of financing for facilities.

- Different port ownership models have different requirements with respect to the structure and returns on investment. In many cases the desired payback period for investment is considerably shorter than the infrastructure's operational life;
- Securing investment on favourable terms is challenging because of the lack of confidence in long term demand for utilisation of the facility, lack of long-term (contractual) commitment to utilise the facility and the perceived risk associated with the ability to maintain repayments for third party debt introduced, which often has a lower cost of finance compared to third party equity;
- For major port development seeking to utilise "conventional" private sector investment, in many cases the port infrastructure is estimated to be unable to generate revenue sufficient to cover associated debt repayments over the desired investment term. In certain cases the difference between the investment required, and the investment which could be sustainably serviced – referred to as the "funding gap" – is significant or very significant (£100-300m). In these cases, investment and associated development can only happen with public sector support which may include grant funding and / or the provision of low interest debt over a long term period (>20 years).

6.5.2 Business and Investment Case –Manufacturing Facilities

- Manufacturing facilities serve regional and national markets and hence are less sensitive to regional variations in market demand;
- Revenue and cost profiles are relatively stable assuming sufficient medium-term demand for the products produced within the facility;
- The investment required in manufacturing facilities is typically moderate when building on existing supply chain capability, or significant (£50-200m), meaning there is large pool of potential investment sources for these facilities;
- They are considered to represent relatively lower risk investment propositions, assuming there is confidence in medium term national demand for their products, and commitment to first orders can be secured. Hence they are more likely to be able to secure long term investment on favourable terms;
- Securing commitment to first orders from the facility, and hence demonstrating market demand and shortening time to first revenue, is key to reaching final investment decisions (FID) – even where the medium-term projections suggest the investment is a relatively lower risk opportunity;
- Where an opportunity is lower risk, this could support being able to secure investment on more favourable terms which reduces the cost of finance, potentially allowing more debt to be taken on;
- In most cases manufacturing facilities themselves are able to secure sufficient private sector investment to facilitate the required investment, assuming there is confidence in the medium-term demand for their products and first orders can be secured;
- Manufacturing facilities offer a secure and stable long-term revenue stream to port infrastructure owners, reducing the risk associated with financing broader port infrastructure development;
- Even where investment is secured for a manufacturing facility, there may be a requirement for investment to be secured from elsewhere to facilitate development of the broader port facility before the manufacturing facility can be developed.

6.6 Facilitating Infrastructure Development and Investment

A number of opportunities exist to address the issues identified in the business and investment case modelling. These are outlined below.

6.6.1 Port Facilities

The scale of the development and investment requirements for the major port infrastructure required to support the delivery of the UK's (fixed and floating) offshore wind targets and broader Net Zero ambition is very significant – with individual infrastructure projects typically requiring anywhere from £50-500m in investment funding (albeit with larger projects likely to be phased) and taking many years to progress through the planning, development and consenting phases prior to construction beginning. A number of fundamental characteristics of large-scale port development act as barriers to private sector investment at the scale and speed required. Some of these characteristics are "offshore wind specific", others are associated with major infrastructure development more broadly. As such, conventional private sector investment models alone are very unlikely to deliver the required speed and scale of port development required. However, a number of opportunities exist to address these barriers. In most cases these opportunities are based on models which have been utilised in other sectors where strategic infrastructure development has been facilitated through appropriate public and private investment models.

Long Term Demand - the risk associated with the aggregate medium- and long-term demand for port facilities in a region presents a barrier to large-scale long-term investment in development of these facilities. Reducing this risk has the potential to increase the scale, and extend the acceptable returns period, of private sector investment in port infrastructure itself. In the context of port infrastructure where offshore wind related activities have the potential to play a major role in generating revenue for a port, a significant factor in reducing risk is the visibility of a long-term pipeline of project activity in that region (long term being defined as over a period similar to the investment return period for private sector investment – between 15-25 years). The provision of medium- and long-term regional deployment targets / rates would build confidence in regional offshore wind deployment to 2050. The likelihood is that different technologies (fixed and floating) will be deployed in different regions and hence this will require either explicit or implicit commitments to the deployment of specific technologies in different regions. It should be noted that these deployment targets would also play a key role in supporting the regional development of appropriate grid infrastructure.

Short- and Medium-Term Utilisation - there is a risk associated with the short- and medium-term utilisation of port facilities in a region, where these are strongly linked to offshore wind related activities, and hence its ability to earn revenue to service debt and / or provide an appropriate return on investment. There are two approaches to mitigating this risk.

- The overall risk associated with investment in major port infrastructure development projects can be reduced by managing regional deployment in a manner such that this maximises the utilisation of port infrastructure, and minimises the overall investment requirement, in that region, over the long term. Typically, this requires steady rates of deployment over the long term – as opposed to peaks and troughs in demand. A coordinated approach to leasing, consenting and the administration of revenue stabilisation schemes on a regional basis would achieve this;
- There is an opportunity for the public sector to further reduce the risk to private sector investors further by providing support which directly (guarantees) or indirectly (revenue support mechanisms) underwrite debt repayments should there be periods where a facility is underutilised - both revenue floor or shared pain / gain models could be considered. A range of potential schemes exist which could be deployed in offshore wind including existing schemes such as the UK Guarantees Scheme. Alternatively, a bespoke scheme could be developed for offshore wind which allows funding from a consortium of offshore wind project developers to

share some of this risk. This would most effectively be coordinated at the regional level, albeit it is likely Government would need to establish a model which could be deployed consistently, nationally. In the context of offshore wind, where the Government plays a key role in the provision of overall energy policy, leasing, project consents and administration of revenue support mechanisms, redistribution of infrastructure utilisation risk has the potential to maximise the scale and speed of private investment in strategic national port infrastructure;

In addition to the mitigations above which are both aimed at reducing the risk to, and hence maximising the investment from, the private sector, direct grant funding and loans from the public sector are also likely to have a role in supporting development for certain infrastructure projects. Existing economic development banks in the UK including the UK Infrastructure Bank (UKIB) and the Scottish National Investment Bank (SNIB) are well placed to support such developments given their strategic national importance and significant impact on GVA.

Fiscal Incentives and International Competition - a wide range of schemes exist which provide fiscal advantages for infrastructure and co-located manufacturing and other commercial activities. These include designations and classifications such as innovation zones, enterprise zones and most recently Freeports (UK) and Green Freeports (Scotland).

The Freeports and Green Freeports schemes have only been developed recently but appear to have a significant impact on the business case for both port infrastructure investment and co-located manufacturing facilities, with recent Freeports in England (Teeside and Humber) being the focus of a number of manufacturing investments relevant to offshore wind.

The use of the current Freeport and Green Freeport mechanisms has the potential to improve the broader business and investment case for major infrastructure development in addition to improving the international competitiveness of facilities and infrastructure. These schemes offer a short term and significant opportunity to support the development of key enabling infrastructure and manufacturing facilities associated with the offshore energy industries and specifically offshore wind.

6.6.2 Manufacturing Facilities

The scale of manufacturing facility investment is typically modest or significant (£50-200m). In general, there is sufficient appropriate private capital available to facilitate the investment in manufacturing facilities where there is a strong medium term market demand for these components in the UK market. However, a number of "offshore wind specific" barriers exist to maximising the scale of private sector investment and / or securing this investment early enough within a market / region to allow facilities to be constructed in advance of need. If not mitigated, these issues will continue to act as barriers to private sector investment in these facilities meaning the facilities will either not be constructed in the UK or the public sector will be required to bridge a funding gap to facilitate construction. Key barriers and opportunities to address these include:

First Orders - securing first orders is typically key to manufacturing facility development investments reaching Financial Investment Decision (FID). These orders are typically placed by Tier 1 suppliers or directly by project developers after an offshore wind project itself has reached FID and relatively close to project construction starting (~1-2 year). At this stage in the industry's development, the Contract for Difference (CfD) mechanism typically plays a critical role in an offshore wind project securing FID. With the construction and commissioning period of a manufacturing facility similar to, or longer than, the period between project FID and the components being required, a fundamental barrier to investment in manufacturing facilities associated with the UK offshore wind industry exists. There are two potential approaches to addressing this issue.

- Allow project procurement commitments to be enabled (in principle at least) earlier in the development process. This could be by evolving the existing Contract for Difference (CfD) mechanism to allow project developers to place (in principle at least) first orders earlier in the development process. This might be facilitated by a scheme similar to the previous Final Investment Decision Enabling for Renewables (FIDER) scheme, albeit with the potential to retain a competitive financial element or by moving away from a predominantly cost driven competitive auction process for revenue stabilisation. For example by setting acceptable revenue support levels sufficiently in advance and encouraging competition in other areas which create value – for example the direct creation of new facilities, employment, environmental improvements. Both these options have the potential to allow orders to be placed, facilities to be built and then orders fulfilled in a timescale which works for both the manufacturer and the project developer;
- Implement a scheme to significantly mitigate or underwrite the risk associated with the potential delay in first / early orders being placed at a facility. This could involve both public and private stakeholders. This may be a challenging model to develop for a number of reasons and would likely be highly component / facility specific.

It should be noted that the two broad approaches above do not need to replace existing mechanisms. They could be developed to augment existing processes and made available selectively where a compelling business case by a project(s) can be made with respect to the facilitation of new manufacturing capacity in the UK.

Other Barriers

The barriers outlined above consider the structural, financial barriers faced by the sector. However, there are a range of other softer barriers which need to be addressed to attract the investment in facilities in the UK – particularly manufacturing facilities. Given the very limited levels of large scale steel manufacturing in the UK at present, significant investment will be required in skills and training to support the development of a competitive workforce for facilities. Such schemes are long term in their approach and impact and as such these need to start well in advance of the construction of the facility itself. There is significant international competition for investment in port infrastructure and particularly manufacturing facilities to establish in offshore wind markets. The role of the long term vision for offshore wind deployment and ability to provide a level of certainty (or some underwriting of the risk) associated with revenues for such facilities need to be viewed in an international context, with the UK presenting a strong and internationally competitive offering. These factors, combined with the structural, financial barriers outlined in this report, mean a coordinated approach by Government, stakeholders, regional development agencies and industry will need to be taken to present a clear overview of the specific scale and location of investment opportunities associated with fixed and floating offshore wind in the UK. These can be informed through direct engagement with industry, and specifically those people and organisations who have delivered, or are currently delivering, such investments to ensure lessons are learned and good practice is identified.

6.7 Infrastructure Investment Requirements Summary

There is a significant appetite from port owners, project developers, major supply chain organisations and infrastructure investors in port and associated manufacturing facility development, but a number of issues mean the current rate of development is not able to deliver the infrastructure at the scale or in the timescales required to deliver short-term deployment targets and in the longer term, a cost-effective transition to Net Zero.

A strategic approach needs to be taken by infrastructure owners, investors, supply chain organisations, project developers and Government to support the cost-effective development of the required infrastructure in advance of need. This needs to recognise the existing barriers to infrastructure development and that the timeliness of this development is critical to the impact this has on the delivery of the UK's Net Zero ambitions.

Short term deployment targets need to be combined with medium- and long-term deployment ambitions on a regional level to determine appropriate and sustainable port infrastructure capacity in those regions for each of the functions described in this report (all of this capability combined being referred to as a "port cluster"). The analysis performed as part of this project can play a key role in supporting this.

Regional port clusters should be developed around one or more facility which can host substructure and FOWT marshalling, assembly and integration for large scale offshore wind projects. This is critical enabling infrastructure around which clusters can be built. It is also highly desirable to seek to develop manufacturing capacity at this same facility. This is likely to improve the business case for the broader port infrastructure investment (by providing stable revenue from long term leasing arrangements with a manufacturer) as well as enhancing the overall offer of the port cluster.

To facilitate the above it is highly likely that some form of public support for a smaller number of key enabling infrastructure developments will be required. The format of this support will depend on the scale of the investment required, the ownership model of the facilities in question, the size of the potential project pipeline in that region and the public sector appetite to share risk. Again, the analysis performed as part of this project can play a key role in supporting this.

7 ECONOMIC IMPACT OF INFRASTRUCTURE DEVELOPMENT

In addition to port infrastructure playing a key role to cost effective project delivery, it will enable significant levels of economic activity – both directly and indirectly. Whilst this broader economic benefit may not offer a direct return to infrastructure investors, it has the potential to provide an excellent return for the UK more broadly through the creation of UK Gross Value Add (GVA).

7.1 Gross Value Add (GVA) Analysis

To assess the impact of critical infrastructure on GVA, a detailed analysis of the GVA associated with ten specific facilities across the UK was performed. These facilities including steel component manufacturing and assembly facilities, concrete substructure construction facilities and FOWT marshalling, assembly and integration facilities.

This analysis is presented on the basis that all substructures for UK floating wind farms will be fabricated, marshalled and assembled in the UK. With this in mind, the forecasts for jobs and economic benefit can be viewed as a high case for fabrication, but a base case for marshalling and assembly given the logistical difficulty of importing this capability.

Costs have been estimated using ORE Catapult's in-house cost model, using a reference 1.5GW FOW site commissioned in 2030. Learning rates have been applied to these costs, using the deployment scenarios to estimate cost reduction through time. Each component of these costs (fabrication, marshalling & assembly) has been mapped against relevant industry Standard Industrial Classification (SIC) codes to calculate the cost of consumption. The remainder is capital and labour income, which gives direct GVA. Indirect GVA has also been calculated using the relevant Office for National Statistics (ONS) multipliers.

Jobs were calculated using input-output tables from 2015 (latest available from ONS) to provide estimated labour / output ratios for components. Salaries were estimated from the Annual Survey of Hours and Earnings, ONS. The labour component of total output was divided by payroll costs for each cost segment to provide an estimate of full-time employee (FTE) years.

There is potential for upgraded ports to provide other services, both to the offshore wind market and other sectors. This has not been evaluated as part of this project, which focuses solely on GVA and job creation from the fabrication and marshalling and assembly of floating wind substructures.

The analysis undertaken highlights the potential economic value and job creation from enabling the fabrication, marshalling and assembly of floating substructures in the UK. Capturing the full market in the UK would generate nearly £40 billion in direct and indirect GVA in the period from 2025 to 2050 (averaging over £1.5 billion per year). It would also create nearly 400,000 direct & indirect FTE years, equivalent to permanently employing more than 15,000 FTE over this timeframe. This analysis only includes floating wind substructures and does not account for other industries which may benefit from enhanced port and yard facilities.

In order for this level of economic benefit to be realised, there are two main elements that need to be in place. First, floating wind must be deployed at scale, growing from 0.1GW today to 75GW by 2050 – as part of a total deployment of offshore wind of 150GW by 2050 which is aligned with the trajectory set by a 2030 target of 50GW of offshore wind. Second, ports and yards must be constructed or upgraded to enable them to supply the whole demand for the floating substructure market. This requires manufacturing, marshalling and assembly capacity of 2GW / annum by late 2020s, 3GW / annum by 2030 and 4 GW / annum by 2040.

The infrastructure development and investment needs in the UK vary between the three main regions where floating offshore wind can be deployed at scale – Scotland, Celtic Sea and North East England. Across Scotland and the Celtic Sea a total of £2.0-2.5bn of investment is estimated to be required to 2030 to enable the UK to deliver a strong pipeline of floating offshore wind projects, and associated targets, in the short term. The £2.0-2.5bn investment includes a total investment in Scotland of £1bn for port infrastructure and £450-750m for manufacturing facilities, with the capacity to deliver 142 units or 2.5GW annually. A further £400-600m is assumed for investment in port facilities and £150-250m for a manufacturing facility in the Celtic Sea region to create a capacity to deliver 40 units or 700MW annually.

A further investment in port infrastructure of £750-950m and £300-450m in manufacturing facilities would then unlock the capacity and capability to deploy a pipeline of 66 units or 1.2GW of floating offshore wind projects in the North East of England. In both Scotland and North East England this investment would also play a key role in supporting the ongoing deployment of increasingly larger scale of fixed bottom offshore wind projects in these regions. Combined, this capability would be sufficient to support the ongoing strong and steady deployment of projects to 2050, following any of the five pathways outlined by the Climate Change Committee. With increasing international offshore wind deployment targets, some of the manufacturing facilities may also have a role in supporting the delivery of projects in neighbouring markets – for example Ireland and Norway.

To better understand the impact this GVA has on the investment case for a specific facility an example is provided below. In this example the initial investment can be compared against GVA over time to calculate a payback period. At the existing site, the economic benefits exceed the investment after just two years operation. This should not be confused with the payback period for the investors themselves, as the investments are likely to be split private/public, and GVA is not returned to investors. However, from a macroeconomic perspective it is useful to understand the broader return compared to investment required.

Note, the example below relates to a specific facility which was analysed in detail. This included an assessment of utilisation of the facility over time which was not assumed to be constant in the short to medium term (hence the reason in the figure below the annual GVA figures vary annually between 2025-2030).

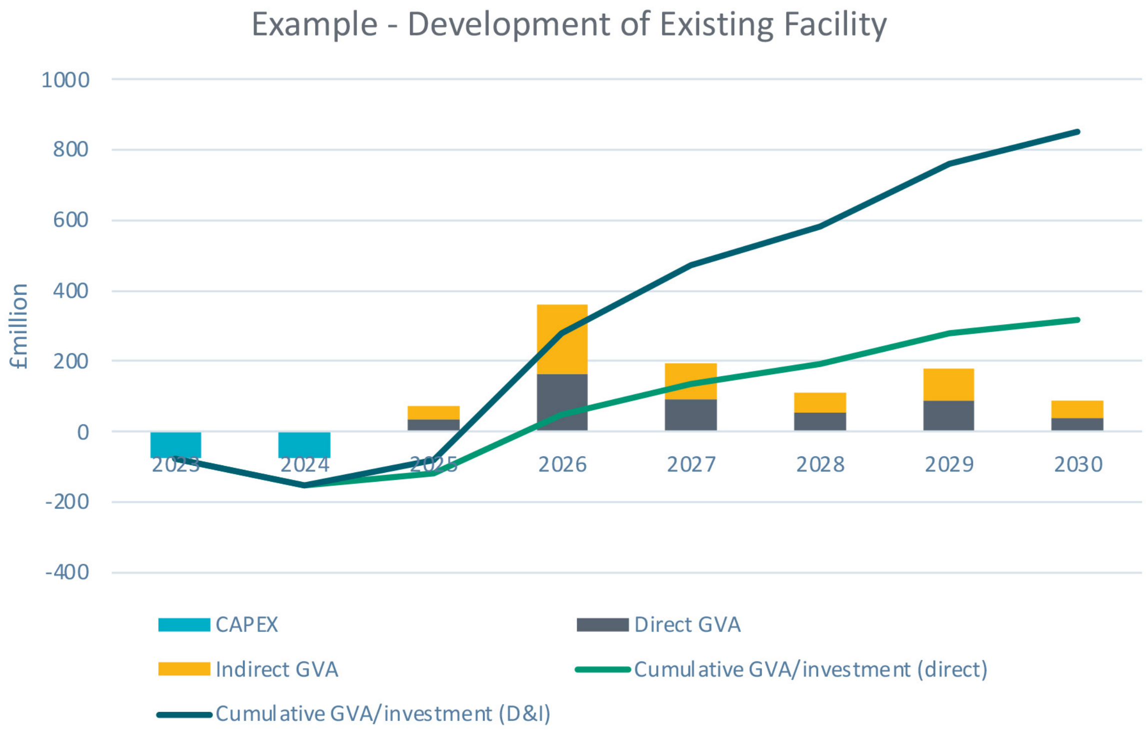

Figure 7: Example of Investment and GVA Forecast for Major Development at Existing Facility

In order to draw broader conclusions regarding the economic impact of strategic infrastructure development, it is useful to assess a larger number of facilities. Figure 8 compares the economic benefit (in direct GVA) with increasing levels of investment into eight separate ports and facilities across the UK. A baseline of ~£3 billion could be captured with existing facilities, with each additional investment resulting in a direct GVA benefit of between 10-15 times the investment for existing facilities. Even for the final two sites requiring over £500 million in investment, the direct GVA benefit is about 2-3 times the level of investment.

Figure 8: Cumulative Infrastructure Investment (Port Infrastructure Only) and Associated Direct GVA

7.2 Economic Impact of Infrastructure Development Summary

The economic impact of the development and operation of key strategic port infrastructure is significant, delivering a significant multiplier effect on the core development investment. Whilst the impact varies from facility to facility, based on an analysis of eight representative facilities across the UK, it is realistic to expect a return of between £10-15 GVA for every £1 invested in existing facilities where moderate or significant development investment is required. Even for facilities where very significant investment is required a multiplier effect is likely to be delivered.

This presents a strong case for public sector support for key strategic infrastructure development. However, it is important that public sector support for infrastructure development is strategically targeted and deployed in a manner which maximises the opportunity for significant private sector funding in this area, hence delivering the highest return on investment for the public support committed – both in financial terms but also by having an impact on other Key Performance Indicators such as skills and training development, supply chain opportunity diversification and increased economic resilience of regions.

8 FINDINGS AND RECOMMENDATIONS

Context
Floating offshore wind will play a key role in the UK delivering a cost-effective Net Zero. Critical to the deployment of floating offshore wind is the development of key enabling infrastructure in the UK. This will also be key to maximising UK GVA in UK projects. In the context of the floating offshore wind opportunity, the role of infrastructure for the manufacture and assembly of substructure components and marshalling and assembly of FOWTs and substructures is critical.

Offshore Wind Deployment Scenarios
Whilst the UK has established world leading Net Zero targets, within which offshore wind will play a key role, there is limited visibility regarding the scale and rate of offshore wind deployment across the UK at the regional level beyond 2030. In addition, the short-term targets which do exist require a sharp increase in deployment rates in the late 2020s. Beyond this the average deployment rates in the 2030s and 2040s being defined by Government policy and its implementation.

Coordination of Deployment and Infrastructure Development
A strategic approach to offshore wind deployment in the UK has the potential to maximise the utilisation of strategic infrastructure including manufacturing facilities and ports. Maximising their utilisation will minimise the overall levels of investment required, and the cost of their use, thereby reducing the cost of delivering the projects themselves. Long-term regional and strategic infrastructure development plans should be created which link regional deployment directly to regional infrastructure development and utilisation.

Floating Offshore Wind Infrastructure Requirements
Floating offshore wind project construction, operation, maintenance and decommissioning has a number of specific requirements with respect to the infrastructure required to support the delivery of these activities cost effectively. Many of these requirements are similar or the same as those for offshore wind. Where they are different, these requirements are not unique to floating offshore wind and hence any infrastructure developed to meet these will have broader application.

Existing Infrastructure Capacity and Capability
As it stands, the UK does not have the capacity or capability of infrastructure requirements to support a number of key project construction activities including steel substructure assembly, concrete substructure construction and FOWT and substructure marshalling, assembly and integration. However, there is an opportunity to develop the capability for manufacturing facilities collocated with marshalling and assembly facilities which brings both operational and commercial synergies, as well as increasing the share of UK content in UK projects.

Investment and Development Requirements
The infrastructure development and investment needs in the UK vary between the three main regions where floating offshore wind can be deployed at scale – Scotland, Celtic Sea and North East England. Across Scotland and the Celtic Sea a total of £2.0-2.5bn of investment is estimated to be required to 2030 to enable the UK to deliver a strong pipeline of floating offshore wind projects, and associated targets, in the short term. The £2.0-2.5bn investment includes a total investment in Scotland of £1bn for port infrastructure and £450-750m for manufacturing facilities, with the capacity to deliver 142 units or 2.5GW annually. A further £400-600m is assumed for investment in port facilities and £150-250m for a manufacturing facility in the Celtic Sea region to create a capacity to deliver 40 units or 700MW annually.

A further investment in port infrastructure of £750-950m and £300-500m in manufacturing facilities would then unlock the capacity and capability to deploy a pipeline of 66 units or 1.2GW of floating offshore wind projects in the North East of England. In both Scotland and North East England this investment would also play a key role in supporting the ongoing deployment of increasingly larger scale of fixed bottom offshore wind projects in these regions. Combined, this capability would be sufficient to support the ongoing strong and steady deployment of projects to 2050, following any of the five pathways outlined by the Climate Change Committee. With increasing international offshore wind deployment targets, some of the manufacturing facilities may also have a role in supporting the delivery of projects in neighbouring markets – for example Ireland and Norway.

Identifying and Addressing Barriers to Infrastructure Investment and Development
A number of barriers exist to unlocking the required investment at the scale and speed required – both for port infrastructure and co-located manufacturing facilities. A number of opportunities have been identified to address these barriers in the short term, as well as ensuring that existing support mechanisms are being utilised to support strategically important development.

Broader Economic Impact
The broader economic impact of strategic infrastructure development is significant with a return of between £10-15 for every £1 invested. For the estimated £2.0-2.5bn investment required to 2030, a total of between £20-37.5bn would be generated in GVA cumulatively by 2050.

This presents a strong case for public sector support for key strategic infrastructure. However, it is important that public sector support for infrastructure development is strategically targeted and deployed in a manner which maximises the opportunity for significant private sector funding in this area, hence delivering the highest return on investment for the public support committed – both in financial terms but also by having an impact on other Key Performance Indicators such as skills and training development, supply chain opportunity diversification and increased economic resilience of regions.

Recommendations
Short term deployment targets need to be combined with medium- and long-term deployment ambitions on a regional level to determine appropriate and sustainable port infrastructure capacity in those regions for each of the functions described in this report.

Regional "port clusters" should be developed in the short term (2022-2024) around one or more "hub" facilities which can host substructure and FOWT marshalling, assembly and integration for large scale floating offshore wind projects. This is critical enabling infrastructure around which clusters can be built. It may also be desirable to seek to develop manufacturing capacity at this same facility – assuming this allows the facility to retain the required marshalling and assembly capacity. This is likely to improve the business case for the broader port infrastructure investment (by providing stable revenue from long term leasing arrangements with a manufacturer) as well as enhancing the overall offer of the port cluster. In the short term this is required in Scotland and the Celtic Sea. Work in Scotland is already progressing in this area following the publication of SOWEC's Strategic Infrastructure Assessment (SIA) in 2021 and a Collaborative Framework Charter (CFC) in May 2022. It is desirable that the capability, capacity and development needs of these port clusters is clearly articulated to present a strong business case for private and public sector investment.

In the short-term (2022-2024) existing support schemes should be focused on developing port clusters in Scotland and the Celtic Sea, with a specific focus on the hubs. Examples of relevant existing schemes include the OWMIS, FLOWMIS, Freeports and Green Freeports.

The use of the current Freeport and Green Freeport mechanisms has the potential to significantly improve the broader business and investment case for major infrastructure development in addition to improving the international competitiveness of facilities and infrastructure and should be used for this purpose. These schemes offer a short term and significant opportunity to support the development of key enabling infrastructure and manufacturing facilities associated with the offshore energy industries and specifically offshore wind – and have the potential to further leverage any funding provided by the FLOWMIS or similar support schemes in the short and medium term.

To maximise the scale and speed of private sector investment in strategic port infrastructure, a dedicated scheme should be developed in the coming years to support large scale investment in infrastructure between 2024 and 2028. The primary role of this scheme should be to underwrite risk associated with port utilisation in the short, medium and long term. This could seek to leverage pooled investment from offshore wind developers and the public sector to underwrite risk, with significant private sector investment directly into the infrastructure development – maximising private sector investment. Any scheme should be deployed alongside medium- and long-term regional deployment ambitions and associated implementation of regional leasing, consenting and administration of revenue support.

Any scheme developed above should include consideration of, and / or be coordinated with other activities to address, the softer barriers the UK will face when attracting investment in port and particularly manufacturing facility investment – specifically skills, training and development, and the ability to clearly communicate the opportunities and approach to mitigations of risks in the context of significant international competition for investment.

APPENDIX 1 EXAMPLE FACILITY SCHEMATICS

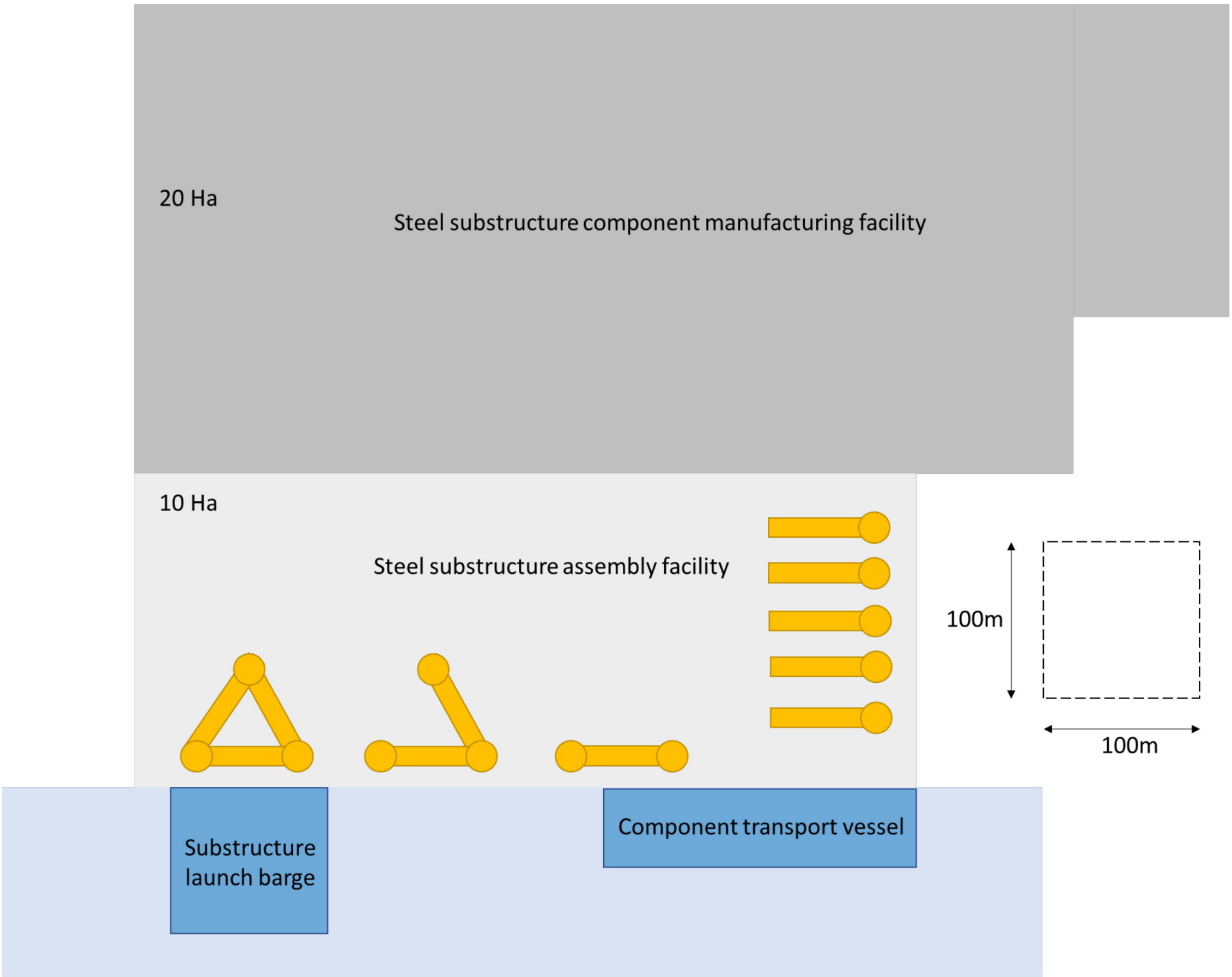

Figure 9: Schematic of Steel Substructure Component Manufacturing Facility and Co-located Assembly Facility

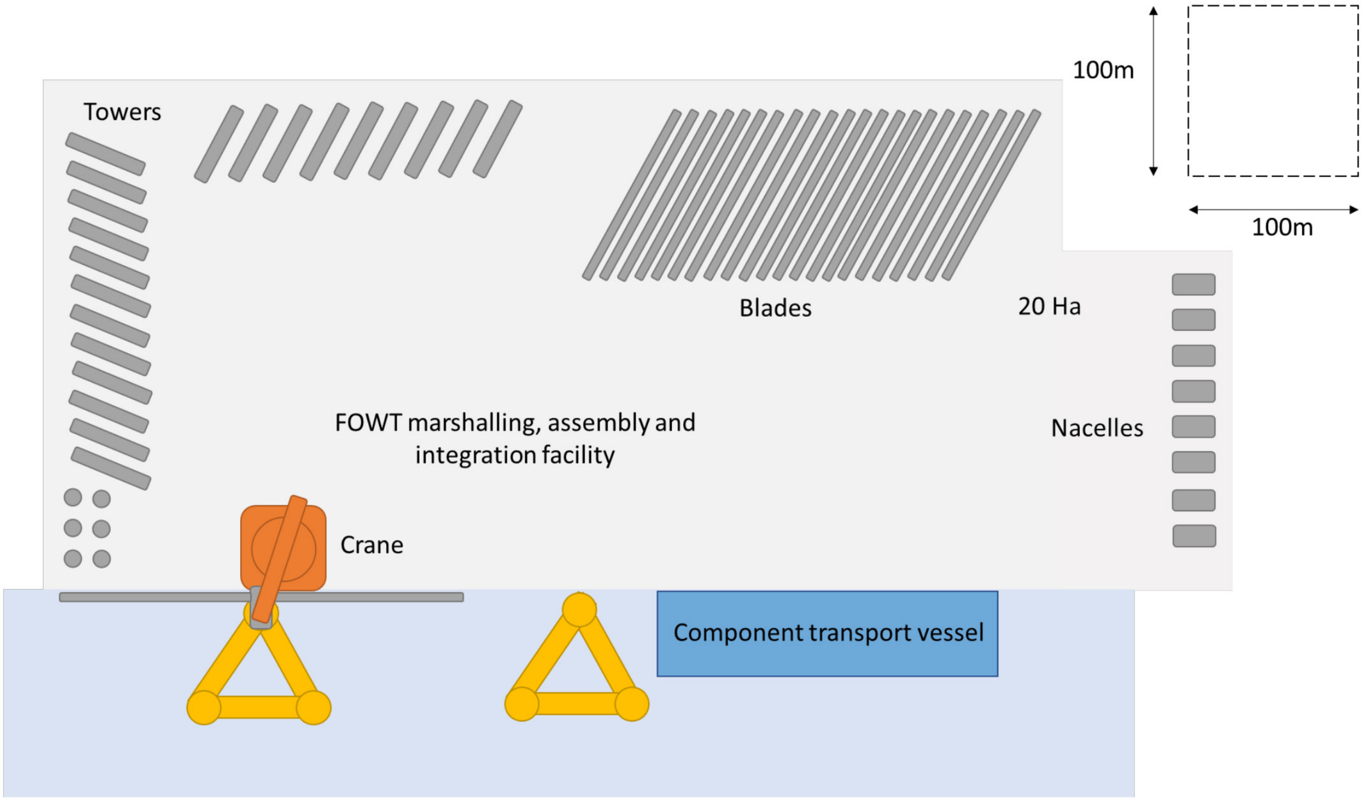

Figure 10: FOWT Marshalling, Assembly and Substructure Integration Facility

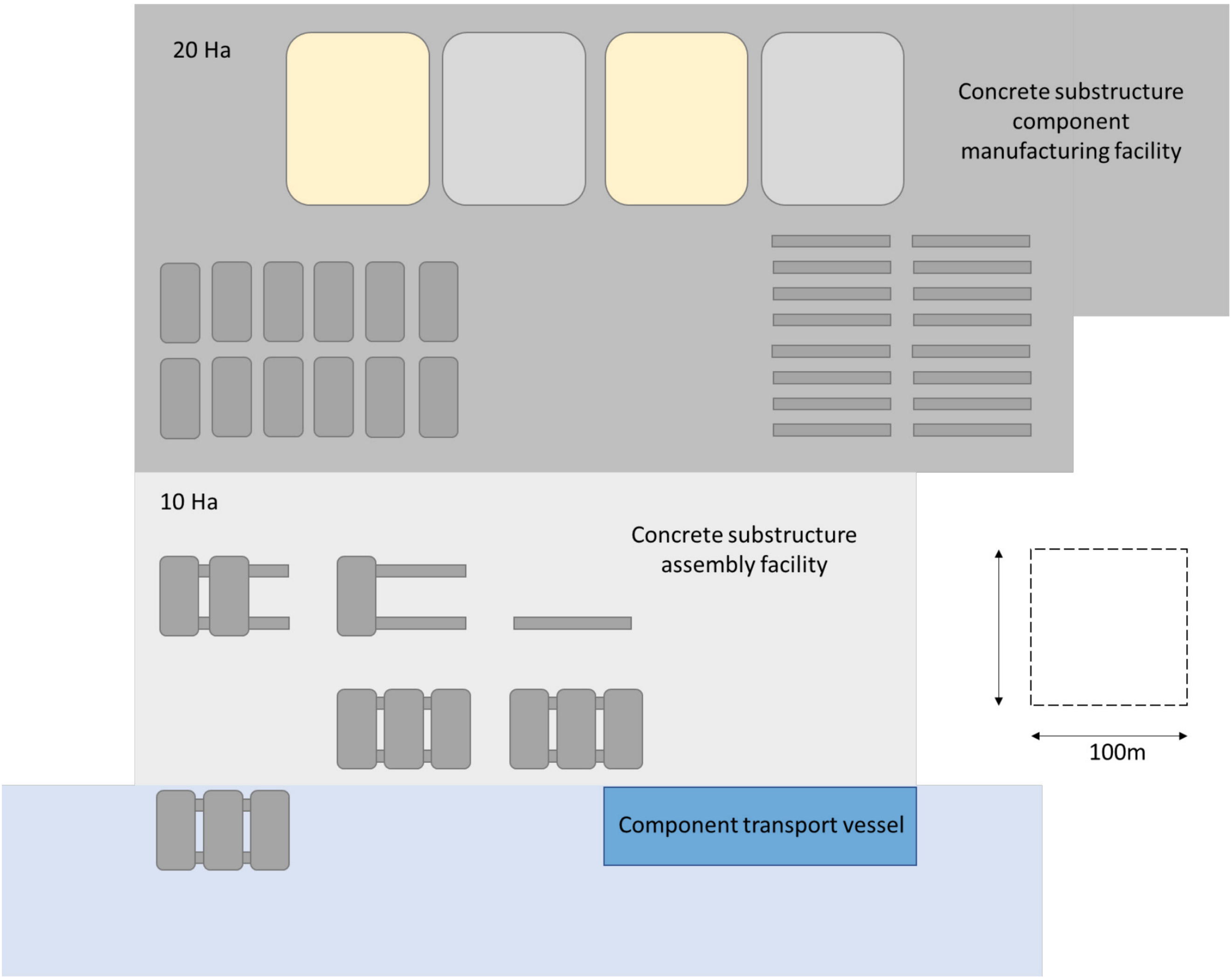

Figure 11: Concrete Substructure Construction Facility

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