In partnership with

Llywodraeth Cymru
Welsh Government

Offshore Renewable Energy

Non-Technical Summary

FLOATING WIND IN WALES
SUBSTRUCTURE AND PORT REVIEW

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CONTENTS

LIST OF ABBREVIATIONS

Acronym	Full-Term
BEIS	Department of Business, Energy and Industrial Strategy
CAPEX	Capital Expenditure
CCS	Carbon Capture and Storage
DC	Direct Current
DNO	Distribution Network Operator
ETYS	Electricity Ten Year Statement
FOW	Floating Offshore Wind
GB	Great Britain
GIS	Gas Insulated Switchgear
GSP	Grid Supply Point
HRA	Habitats Regulations Assessments
HVDC	High Voltage Direct Current
ITPE	ITPEnergised
LCOE	Levelised Cost of Energy
MER	Maximising Economic Recovery
NGESO	National Grid Electricity System Operator
NGET	National Grid Electricity Transmission
NOA	Network Options Assessment
O&G	Oil and Gas
O&M	Operations and Maintenance
ORE Catapult	Offshore Renewable Energy Catapult
OTNR	Offshore Transmission Network Review
PDZ	Pembrokeshire Demonstration Zone
SQSS	Security and Quality of Supply Standards
TCE	The Crown Estate
TEC	Transmission Entry Capacity
TNUoS	Transmission Network Use of System
TWR	Transmission Works Register
UK	United Kingdom
VSC	Voltage Source Converter
WMO	World Meteorological Organization
WPD	Western Power Distribution

FOREWORD

We have worked with the Offshore Renewable Energy Catapult (ORE Catapult) to develop our understanding of what the floating offshore wind sector requires in Wales, with the aim of maximising the economic benefits associated with the estimated 70GW of generation within UK waters of the Celtic Sea.

As part of this collaboration, in 2020 we published the supply chain report, 'Benefits of floating offshore wind to Wales and the South West', which identified a number of critical recommendations for further analysis. We have now completed two additional reports mapping out the state of play of our grid and port infrastructure across Wales to support the development of offshore renewable energy.

This particular report details how Welsh ports could play a significant role in building a sustainable future for Wales by unlocking opportunities for floating offshore wind within the Celtic Sea. We recognise that the report is the first step on our journey and that we need further strategic consideration and capital investment to unlock our long-term potential. Key findings include the requirement to promote collaboration across our ports and to engage with both the Crown Estate and UK Government to create market certainty for the sector.

I want to confirm that we have already stress-tested the findings and are working alongside our ports and a wide range of project developers to further probe what is required. Alongside this, we have been working closely with the Crown Estate to bring forward a dedicated floating offshore wind seabed leasing programme for the Celtic Sea. Only with this market certainty, will investment be unlocked.

The report also clearly demonstrates the economic opportunity for Wales should a long-term project pipeline be realised. This will require the Crown Estate to develop a dedicated seabed leasing programme for the Celtic Sea which accelerates from early to full commercial scale over a reasonable timeframe. Alongside this, UK Government need to continue to provide clear signals to the market regarding revenue support.

To conclude, fit for purpose port infrastructure will be critical in unlocking our ability to develop high quality and sustainable employment in Welsh coastal communities.

Vaughan Gethin, MS,
Minister for the Economy

1 BACKGROUND

1.1 OFFSHORE WIND IN THE UK

There is a large existing portfolio of bottom-fixed offshore wind off the coast of North Wales, and 3.5GW of new seabed leases recently awarded in The Crown Estate's (TCE) Round 4 Auction. The Port of Mostyn has a long history of working with fixed wind developers in the region and it and other North Wales ports are actively engaged with new project developers in this area and the waters between Wales and Ireland. It is anticipated that this activity will be the primary focus of the ports in North Wales over the medium to long term.

Bottom-fixed offshore wind costs have reduced over time, and Contracts for Difference are now priced at a near 'subsidy-free' basis. The focus from the Department of Business, Energy and Industrial Strategy (BEIS) and Office of Gas and Electricity Markets (OFGEM) is now on UK content in new offshore wind projects. In the Offshore Wind Sector Deal, the UK's offshore wind sector has committed to increase UK content to 60% by 2030, including increases in the capital expenditure phase. The 60% UK content target is recognised as being challenging, with much of the capital costs of a new windfarm being difficult to capture in the UK. The manufacturers of the high-value turbine nacelles, for instance, are all currently non-UK companies.

While these are heavy components, they are also relatively compact and transportable, and these components are unlikely to be manufactured in the UK.

Another big component of capital cost is the installation of these turbines at sea. For bottom-fixed turbines, and big part of the installation costs is the hiring of large vessels, such as jack-up barges, to assist with the installation process. These vessels are largely foreign-owned and operated, once again making it difficult to capture the value in the UK. However, for floating offshore wind (FLOW), the turbines will be installed on their foundations in a port, in a process known as 'turbine staging'. This obviates the need for heavy lift and jack up vessels at sea and allows the port to capture a significant share of the capital costs of deployment. If a UK port is used, then this can significantly boost the UK content, above that which might be expected for a bottom-fixed deployment.

1.2 FLOATING OFFSHORE WIND IN WALES AND THE CELTIC SEA

The Climate Change Committee stated in 2020 that 100GW of offshore wind is likely by 2050[1], of which ORE Catapult estimates 42GW will use floating wind technology. In deployment scenarios set out in the report 'Floating Offshore Wind Cost Reduction Pathways'[2], published in January 2021, ORE Catapult estimates that by 2040, 4.9GW floating offshore wind may be constructed in the UK waters of the Celtic Sea.

Bristol based consultancy ITPEnergised have undertaken a resource assessment of the potential for floating offshore wind capacity that could be deployed in the Irish and UK waters of the Celtic Sea for

Simply Blue Energy[3]. Using GIS mapping to identify constraints, consenting issues and suitable environmental conditions, they identified ten potential zones for development as shown in Figure 1.

1. https://renews.biz/64064/gow20-next-stop-for-uk-100gw-by-2050/
2. https://ore.catapult.org.uk/?orecatapultreports=floating-offshore-windcost-reduction-pathways-subsidy-free
3. Assessment of the floating offshore wind potential in the Irish and UK waters of the Celtic Sea, Simply Blue Energy, 2019

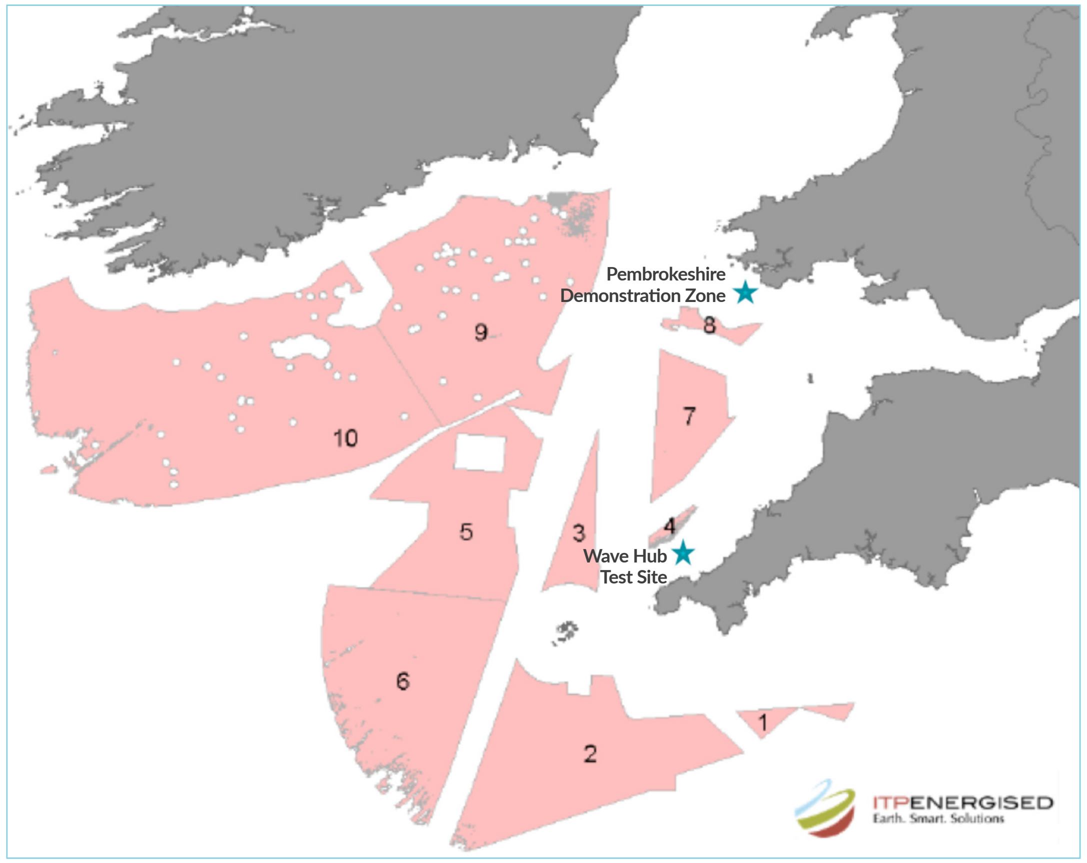

Figure 1: Potential zones of floating wind development as identified by ITPEnergised

These zones have average wind speeds exceeding 10 metres per second. Taking account of further grid, environmental and technical constraints, ITPEnergised suggest that between 15 – 50GW of the 150-250 GW total floating offshore wind capacity could realistically be developed in the Celtic Sea region. These zones are suggested as one set of high potential areas for FLOW development. They have not been endorsed by TCE, who will conduct their own exercise ahead of any future seabed leasing rounds.

1.3 STEPPING STONES AND FIRST MOVER ADVANTAGE

Successful early deployments of floating wind have significantly de-risked the technology. Oil & Gas majors making an entry to FLOW are confident in the technologies due to their experience of floating platforms in their existing operations. Nevertheless, it is to be expected that initial floating wind projects will still be small. Total, for instance, have publicised their 'stepping stones' approach to developing floating offshore wind.

Early FLOW developments in Wales could give the Welsh supply chain a 'first mover' advantage, demonstrating capability and capacity, and gathering experience that would enable more successful bids into the larger projects that would follow. However, the smaller stepping stone projects are not, in themselves, big enough to justify investment by ports to construct the facilities necessary to capture these early developments. For commercial scale projects, significant investment is needed, and external support for that investment may be required. One motivation for this report is to identify the current gaps in capability and capacity that might be barriers to capturing an early mover advantage.

1.4 SUBSTRUCTURES FOR FLOATING WIND

The key difference between floating offshore wind and bottom-fixed offshore wind is in the type of structure used to support the wind turbine. Bottom-fixed offshore wind is a more mature industry, and it is currently dominated by monopile foundations (81.5% of all installed foundations are monopiles). In floating wind, it is not clear which substructure design(s) will succeed, as there is little experience to date and new designs are constantly being proposed. Floating foundations generally fall into four categories, as illustrated in **Figure 2**.

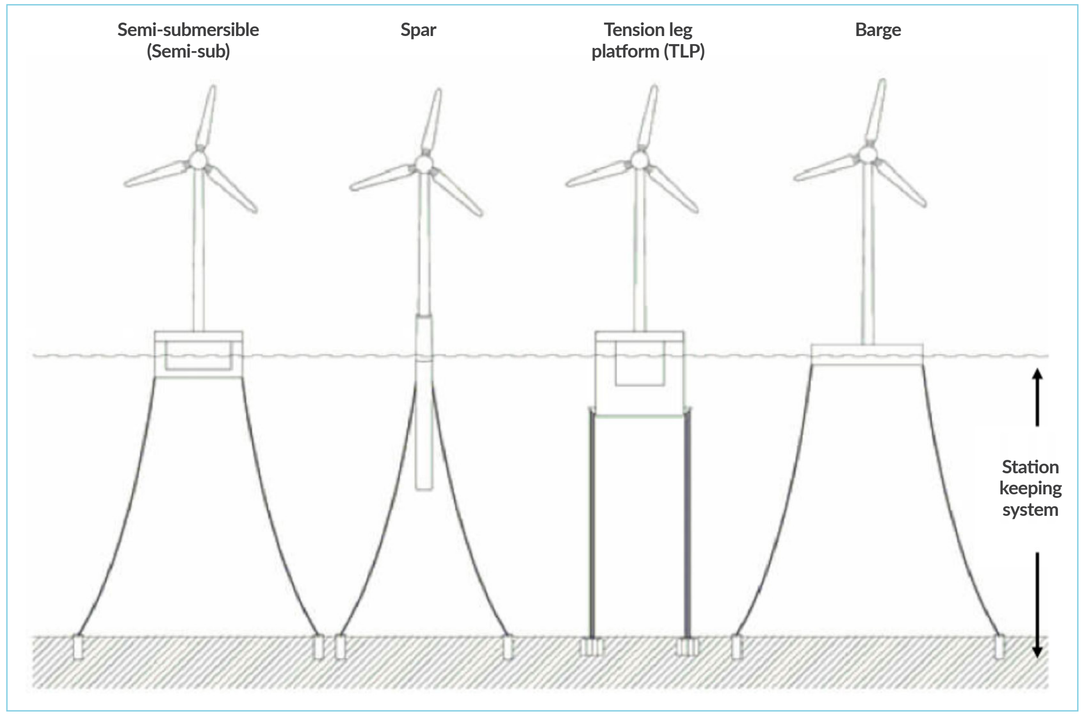

Figure 2: Different types of floating foundation for offshore wind turbines. Source: DNVGL (2018)

1.5 WINDFARM DESIGN USED IN WELSH CASE STUDIES

1.5.1 Substructure

Spar foundations were used for early FLOW demonstrators, but require very deep water and very deep harbour and port facilities, and as such are unsuitable for Welsh waters. Semi-subs, TLPs and barges are all suitable for Welsh waters. However, the large tidal range seen around Wales makes TLPs less attractive. Barges could be used, but steel and concrete semi-subs are felt to be most appropriate, and will be the focus of this report. The physical parameters used in this study are shown in **Table 1**.

The choice of material can have a big effect on local content, depending on existing capabilities and capacities. The UK, for instance, no longer has many facilities capable of rolling the larger steel components for some floating semi-subs. Concrete capability in the UK is much more widespread. The choice of material seems to be designer dependent, with civil engineering companies often favouring concrete over steel as they are more familiar with it, and vice versa for offshore oil & gas companies. Whilst steel is currently the more popular choice of material, the number of concrete designs has steadily increased over the years. More detail is available for steel designs, and a major part of the analysis in this report is given over to steel semi-subs, but concrete manufacture was discussed with all the ports contacted.

Table 1: Substructure parameters used for this study

Parameter	Semi-sub (concrete)	Semi-sub (steel)
Substructure mass (t)	12,000 – 15,000	3,000
Mass to power ratio (t/MW)	800 – 1,000	200
Height (m)	30	30
Beam/width (m)	90	70

1.5.2 Turbine

A 15MW turbine was chosen for this analysis to reflect where the industry and available wind turbine ratings are expected to be when floating wind becomes fully commercial.

Provided in **Table 2** are parameters for a hypothetical 15MW wind turbine used in the study.

Table 2: Parameters for a 15MW Wind Turbine as used for this study

Parameter	Value	Parameter	Value
Rotor diameter (m)	220	Nacelle length (m)	20
Blade length (m)	105	Nacelle mass (t)	650
Blade mass (t)	40	Tower height[4] (m)	120
Blade root diameter (m)	6	Tower diameter at the base (m)	8
Nacelle height (m)	10	Tower mass[4] (t)	1,000
Nacelle width (m)	10		

4. Tower height and mass are site and substructure dependent.

2 ASSESSMENT OF WELSH PORT CAPABILITY FOR FLOATING WIND

2.1 METHODOLOGY

A review of Welsh ports and harbours within the British Ports Association Directory was undertaken. The sites that showed general cargo and commercial quays (rather than leisure moorings and fishing berths solely) were contacted for further information. The port owner groups that have already commenced significant infrastructure master planning and expressed aspirations for offshore wind, floating offshore wind, wave, and tidal stream to Welsh Government, were prioritised for this study, and these are shown in **Figure 3** below with their ownership highlighted within the embedded table.

Ports in Wales

Port	Assessed	Owner
Cardiff	No	ABP
Barry	No	ABP
Newport	No	ABP
Port Talbot	Yes	ABP
Swansea	No	ABP
Pembroke	Yes	Milford Haven Port Authority
Fishguard	No	Stena Line
Holyhead	Yes	Stena Line
Mostyn	Yes	Privately Owned
Milford Haven	Yes	Milford Haven Port Authority

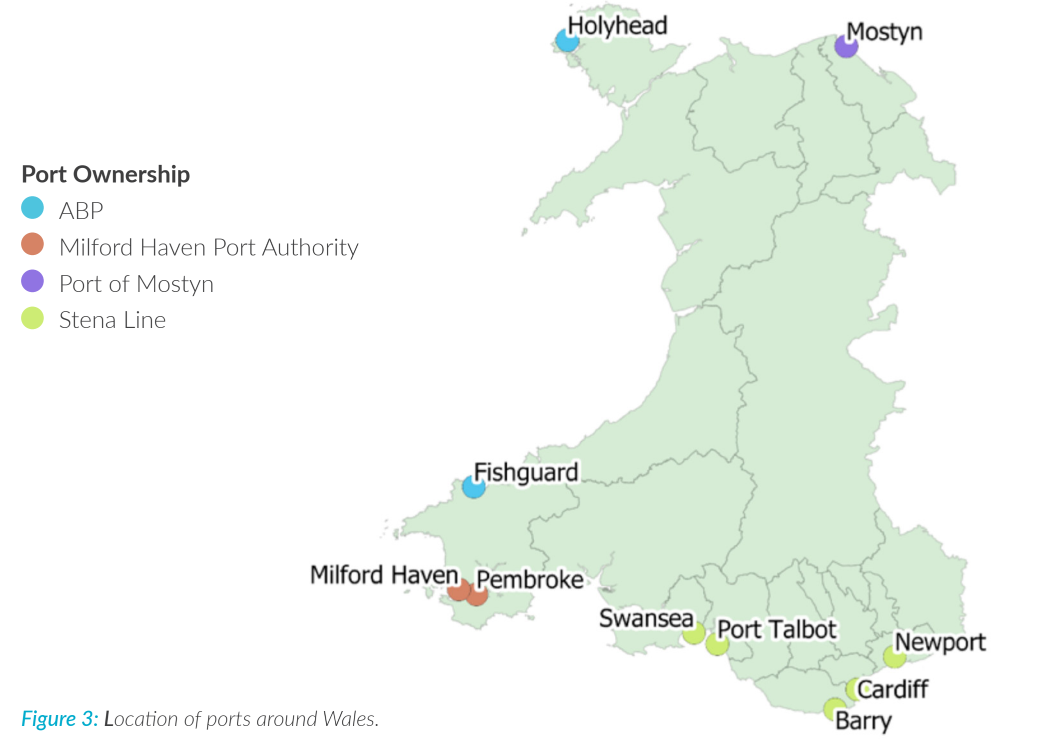

Figure 3: Location of ports around Wales.

With a cover letter from Welsh Government by way of an introduction and setting of context, the 4 major port owners were sent questionnaires. Each owner was then engaged, separately, in a virtual workshop, provided with a slide pack, including their own site maps and proposed expansion areas, along with process flow diagrams. The initial workshop investigated each stage of the process overlaid graphically on a port schematic. What was found was that the majority of the ports had various options for land expansion and use and required additional input within and following the workshops on the potential layouts for their sites.

To facilitate discussions, the ports were furnished with a document of numerical assumptions regarding the size, weight and numbers of components, and follow-up workshops and phone calls were held for clarifications.

2.2 PORT SERVICES FOR FLOW

Port services in this context fall into three basic categories:

- Water depths that allow the movement of large floating structures in and out of the port; the ability for these large structures to be moored alongside a quay; and quayside facilities that allow large structures to be loaded and unloaded across that quay.
- Large contiguous areas of laydown space to accommodate storage of components and subassemblies, such as turbine blades, tower sections, nacelles etc.
- Engineering and construction facilities for making the foundations and components thereof.

For each port, data was gathered to assess that port's suitability to provide services to floating wind using information provided in questionnaire format. The type of information gathered included:

- Navigational channel width, depth and ceiling (air clearance to bridges, transmission lines)
- Length and number of berths and their depth
- Maximum serviceable vessel length, beam and draught
- Available infrastructure – space (existing and for future development), road and rail access, cranes, dry dock
- Local amenities
- Access to workforce

A particular emphasis was placed upon potential for developing lay down, additional quays of an appropriate depth and buildings that could be suitable for fabrication needing clean, indoor areas.

2.3 THE FLOATING WIND FARM DEPLOYMENT PROCESSES

A generic floating wind farm deployment would involve the following processes:

Floating foundation manufacture and storage
Foundations are manufactured, either from raw materials such as sheet steel or concrete, or assembled from larger sub-components manufactured elsewhere. This is usually done on land, although the use of floating dry docks is possible. As foundations are manufactured in advance of requirement, it is necessary to be able to store foundations until they are needed. This could be on land if sufficient space is available, or alternative at sea, in a sheltered area (wet storage).

Mooring storage
Mooring chains and anchors are stored on a quayside, until required. Mooring chains do not need specialised storage, but can damage quay surfaces, so may require repairs to be done before that quay area can be used for other purposes. Whether mooring chain storage happens in parallel with wind turbine component lay down depends on the project developer. It is possible to install mooring systems at sea well in advance of turbine deployment.

Wind turbine component lay down.
The turbine nacelle, blades, and towers (usually in 2 or 3 sections) are brought to the wind turbine staging port and stored in a lay down area. Typically, the wind turbine staging port would require enough lay down space to store, at any one time, from one third to half of the components necessary for the complete wind farm.

Wind Turbine Staging and Deployment
The activity of placing all the wind turbine components on to a floating foundation is called staging. This final port process is carried out immediately before deployment of the completed floating turbine to its final wind farm site. This can be done completely on a quayside, if there is the capability to then get the completed device across a quayside into the water, or more often it is done with the floating foundation moored alongside a quay. This is a risky process and must be started and completed in good weather (particularly low wind conditions) and so it is essential that all components are near to hand.

2.4 PORT STRATEGIES FOR FLOATING WIND DEVELOPMENT IN WALES

Floating wind substructures to be installed in Wales could be fabricated locally in Wales, in the wider UK or farther abroad. The adopted approach by project developers is mainly cost driven, which in the case of Wales compares higher manufacturing costs and lower transportation costs in Wales with lower manufacturing costs and higher transportation costs elsewhere (e.g., Spain or South Korea). Three floating wind projects have been developed or proposed in Scotland with the following port strategies:

- **Hywind Scotland** – Five spars were fabricated and fully assembled by Navantia in Spain, then shipped to Norway, where they were up-righted and wind turbines installed. The fully assembled units were then towed to Scotland and hooked-up to pre-installed electrical and mooring systems. The suction anchors were fabricated in Scotland by Nigg Energy Park.
- **Kincardine** – Six steel semi-sub structures will be fabricated and fully assembled in Navantia in Spain. These will be towed across to the UK and wind turbines installed on them, before being towed to the site and connected to preinstalled infrastructure.
- **Hexicon** – The project, now cancelled, proposed to assemble one unit at Nigg Energy Park using pre-fabricated components made in South Korea. The same port was suggested for wind turbine staging and installation before the tow to the site for hook-up.

The ability of the country and its ports to deliver substructures is also considered by the project developers. This is less applicable to demonstration projects and pre-commercial arrays that consist of a small number of units and more applicable to fully commercial arrays, which could be beyond the capability of a single port. The limiting factors include such considerations as throughput of material, water depth, quayside characteristics and spatial restrictions of the port.

2.5 COMBINING PORTS IN FLOW CONSTRUCTION PROJECTS

A port could be used for different stages of floating wind farm construction:

- **Pre-fabrication** – Pre-fabrication of substructure components (steel or concrete).
- **Assembly** – Assembly of substructures using pre-fabricated substructure modules (steel or concrete)[5].
- **Wind Turbine Generator (WTG) Staging** – Wind turbine staging and installation on substructures.

Using the substructure related activity breakdown, four different strategies could be used to execute work in construction of floating wind projects (**Figure 4**).

5. It should be noted that concrete substructures can be slip formed (no requirement for pre-fabrication).

ASSESSMENT OF WELSH PORT CAPABILITY FOR FLOATING WIND

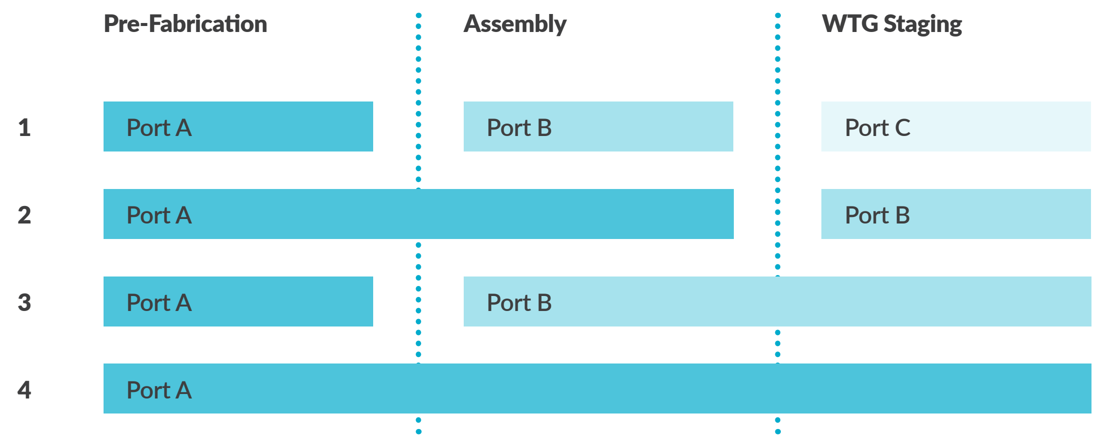

Figure 4: Work Breakdown Options Between Ports.

Mooring line (typically steel chain or synthetic rope) fabrication would be performed in dedicated facilities, whilst anchors could be fabricated at a port as was the case for Hywind Scotland. Mooring system (mooring line and anchor) staging could be performed in a separate port or in a combination with any of the above options in **Figure 4**. Note that there is a lack of capacity for manufacture of conventional mooring chains globally. It is understood that Tata Steel in Port Talbot produce steel suitable for mooring chains, and it has been suggested that there are companies interested in developing mooring chain manufacturing facilities in Wales if there were a suitable investment case.

Electrical cable fabrication would be performed in dedicated facilities (e.g., JDR in Hartlepool or Prysmian in Wrexham) and taken directly to the site for installation using a cable laying vessel without a need for intermediary port facilities. While Prysmian do not currently have an 'end to end' process in Wales, this could be developed if there were sufficient evidence of demand to justify investment.

2.6 SUMMARY OF WELSH PORT CAPABILITIES

The primary criteria were the port's physical characteristics (e.g. area, water depth) rather than the machinery and equipment available on the site (e.g. steel working capabilities, paint and blast shops), as such facilities can be readily acquired. Physical characteristics, on the other hand, can set fundamental limits (e.g. no expansion opportunities, no opportunity to dredge the quayside).

Pre-fabrication of substructures covers steel concepts that can be prefabricated into sections before the final assembly into a full unit, potentially at a different port. However, assembly of substructures covers both assembly of steel substructures, as well as fabrication/slip forming of concrete design.

A number of well-placed ports have been identified to offer services in floating wind farm construction (component pre-fabrication, substructure assembly, WTG assembly and mooring system staging). Ports that did not score highly for the construction phase, mainly due to limited available space, could be used as O&M bases, which have significantly smaller footprint requirement at the port.

This study looked at the existing capacities and facilities of the ports as a starting point. It also considered existing development plans that some of the ports have, and it further looked at the possibility of future infrastructure development at each port that might release extra capacity and capabilities.

Currently no Port in Wales has the capacity to deliver all the functions and services required to deploy a floating wind development. The limitations are broadly as follows:

- **Fabrication, Assembly and Staging** – Port Talbot seems capable of being upgraded to take on the whole process, from fabrication to deployment. The upgrades necessary for this are significant and go beyond plans that the port already has in place.
- **Assembly and Staging** – There are three ports (Port of Mostyn, Port Talbot and Pembroke Dock) that could, after investments beyond those already planned, host both substructure assembly and wind turbine staging. For two of these ports, the investment and restructuring would be significant, and there remain concerns which could prevent the benefits from being realisable.
- **Wind Turbine Staging** – Two ports, Port of Holyhead and Pembroke Dock, already have investment plans that, if completed, would allow them to host wind turbine staging. A further two ports, Port of Mostyn and Port Talbot could join these if they invested in significant, currently unplanned, infrastructure upgrades.
- **Mooring Staging** – Three ports, Port of Mostyn, Port of Pembroke Dock and Port Talbot would have the capacity to handle mooring and anchoring staging once planned upgrades are in place. The Port of Holyhead could be upgraded to handle this activity if significant upgrades, beyond those planned, were put in place.

3 USE OF WELSH PORTS IN FLOW PROJECTS

3.1 CASE STUDIES

Two case study locations have been chosen to demonstrate representative Welsh FLOW projects, shown in **Figure 5**; a 'North Wales' site and a 'South Wales' site.

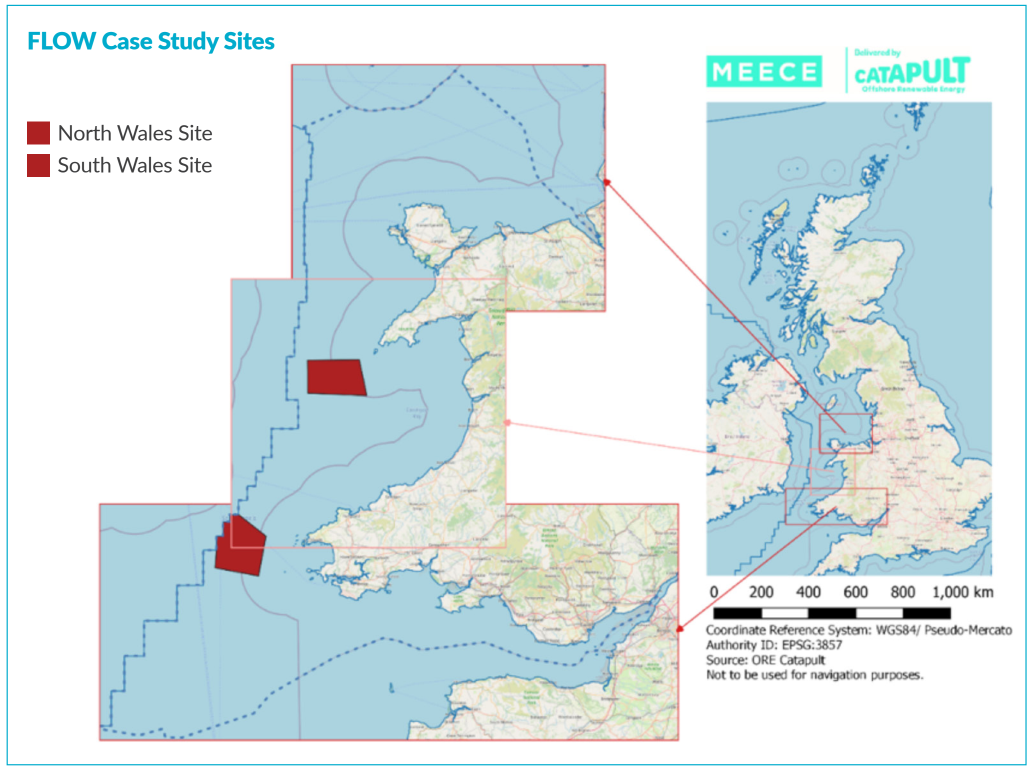

Figure 5: Map of Welsh FLOW case study locations.

The exact location of each wind farm is not crucial to the discussions in this report, and is derived from the report Floating Offshore Wind: Cost Reduction Pathways to Subsidy Free[6].

Table 3: Parameters for a 15MW Wind Turbine as used for this study

Case Study		South Wales	North Wales
Average water depth	m	115	80
Distance to port	km	60	75
Grid Connection Zone		Pembrokeshire	Pentir
Distance to cable landfall	km	40	38
Onshore cable distance	km	10	63
Mean wind speed at site (@ 150m height)	m/s	10.7	9.9
Annual mean significant wave height	m	1.9	1.5
Seabed conditions (see Table 2)		Hard	Normal

6. https://ore.catapult.org.uk/?orecatapultreports=floating-offshore-windcost-reduction-pathways-subsidy-free

Table 4: Details of case study sites

Potential Seabed Conditions		
Type	**Description**	**Soil conditions**
Weak (holding power)	Unfavourable conditions due to weak holding power of seabed requiring larger anchors. Possible seabed movement and scour.	Soft mud
Normal (holding power)	A number of different anchors could be used on site (e.g. drag-embedded, suction, gravity, pilled). The most optimal seabed conditions from mooring CAPEX.	Sand, sandy mud, mud, clay
Hard	Hard seabed prohibiting use of drag-embedded and suction anchors. Most appropriate gravity base or drilled.	Rock-based (e.g. basalt)

The key site parameters for each location are shown in **Tables 3 & 4**, and have been used to provide a cost estimate for projects at each location, and to estimate component volumes required, for example chain length and anchor technology choices. At each location, a port strategy has been developed for a 300MW project and a 1,000MW project to represent an early commercial and mature commercial project to investigate the types of work flows ports may be asked to provide for FLOW projects and inform long term port strategies.

3.2 PORT SELECTION

Based on the port assessment in Section 2, Holyhead, Mostyn, Milford Haven and Port Talbot ports were selected for the case study discussion, this selection was primarily based on proximity to site and currently available or potential infrastructure at ports by 2030.The scope for each port for each of the case study sites are shown in **Tables 5 & 6**.

- Port Talbot is used for substructure assembly in all steel semi-sub scenarios. There are efficiencies in developing a single site to specialise in the activity, rather than developing two sites for the same purpose that may not have the long-term throughput to justify the upfront expense.
- It is wholly feasible that Mostyn could undertake this activity, followed by turbine installation at Holyhead, however with new leasing in Ireland and through Auction Round 4 in the UK, FLOW projects will have to compete with bottom-fixed offshore wind installation for use of these ports. Nevertheless, we show these ports as an optional strategy in **Table 6**.
- In the North Wales case study, Holyhead has been modelled as the staging site for mooring line and anchor installation. A port close to site has been chosen as installation uses anchor handling vessels with a limited deck capacity. This means a high number of journeys are required to install all the anchors and mooring lines for a site. A shorter distance is preferable for this repetitive operation. For the same reason, Port Talbot has been assumed for the South Wales case study.
- For both case study sites, Port of Milford Haven has been assumed as the prime turbine installation location and launch to site, based on the assessment that the site has optimal channel depths and low wind speeds to undertake the turbine installation. The metocean conditions means there are fewer limits on towage due to tides. For the 1GW case studies, the waterway is the most suitable location for substructure storage over winter. Other non-port sheltered locations are likely available but have not been fully explored in this report. For the North Wales case study, Holyead is also an option for wind turbine staging.
- Choice of port for wind turbine staging is driven by proximity to site. It is important to be able to leave prot, tow to site and deplyo within a 72-hour weather window. At a towing speed of 3 knots, both the North and South Wales case studies are well within the towing distance of Pembroke Port.

3.3 SOUTH WALES CASE STUDY PORT STRATEGY

Table 5: South Wales Case Study Port Strategy

Port Activity			
Substructure Assembly (steel)	Port Talbot		
Concrete Substructure	Pembroke Port		
Mooring Line & Anchor Assembly		Port Talbot	
Wet Storage			Port of Milford Haven
Turbine Assembly			Pembroke Port

3.4 NORTH WALES CASE STUDY PORT STRATEGY

Table 6: North Wales case study port strategy

Port Activity (Option strategy in blue)			
Substructure Assembly (steel)	Mostyn / Port Talbot		
Concrete Substructure	Mostyn / Pembroke Port		
Mooring Line & Anchor Installation		Holyhead	
Wet Storage			Holyhead / Mostyn / Port of Milford Haven
Turbine Assembly			Pembroke Port

3.5 ALTERNATIVE CONSTRUCTION PORT SOLUTIONS

This study has focused on maximising the potential of existing port facilities in Wales. However, there are several companies developing concepts for temporary or floating solutions to complement existing facilities, such as those incorporated in the case study, or operate as standalone facilities that can be assembled and dis-assembled as required. These alternative solutions could be seen as more cost-effective long term solutions than conventional port infrastructure upgrades, although costs are likely to be very location-specific. As some of these options also have a much shorter lead time than port infrastructure upgrades, they could also be used in parallel to longer term investment, in order to capture early local content from the first, small floating wind developments, such as Erebus.

4 ECONOMIC BENEFIT OF FLOW PORT ACTIVITY TO WALES

Based on industry engagement, ORE Catapult has built a bottom-up analysis of the expected cost of each activity for the case study sites described in Section 4.1. Each process defined in the previous sections has been broken down to identify the facility cost, plant cost and labour cost associated with each activity. The case study assumes the allocation of work scopes to ports as described in Section 3.5.

- Facility cost covers ongoing port charges associated with specific activities, such as heavy lift, use of quayside, use of existing assets (small cranes, bulldozers and other plant equipment) as well as an ongoing rental for exclusive use of large areas of the port for storage and assembly space.
- Plant cost describes the use of equipment including cranes, bulldozers, and access towers to assemble and install structures.
- Labour cost covers all employees involved in the tasks involved in the assembly and installation of structures.

A learning rate has been applied to the costs, assuming the 300MW project is undertaken in 2028 and the 1,000MW project is undertaken in 2030. This adjusts costs to reflect advances expected in substructure design and manufacturing processes based on lessons learned in previous projects. All costs have been estimated to the best of our knowledge at time of writing based on engagement with ports, fabrication yards and substructure developers.

According to the UK Foundations Strategic Capability Assessment[7] conducted by ORE Catapult in 2020, steel fabrication is estimated to cost 10-15% more in the UK or Europe versus the most competitive prices achieved in the market. However, components sourced from further afield incur higher transport costs and supply chain have remarked that a higher proportion of structures have required remedial work when arriving in the UK, causing unforeseen cost increases and schedule delays.

The costs quoted in the following sections exclude major investment required for the site to undertake substructure assembly contracts, e.g., the manufacture of a new quayside but does include provision for project preparation, e.g., surface preparation. Major investment will likely be recouped over a series of projects at the port and will increase the facility cost. It is difficult to accurately estimate how this may increase project costs based on how port upgrades are funded, and what visible project pipeline a port can expect to recoup their costs through.

7. https://ore.catapult.org.uk/wp-content/uploads/2020/01/UK-OSW-Foundations-Strategic-Capability-Assessment-2019-v04.03.pdf

4.1 SUBSTRUCTURE ASSEMBLY

Substructure assembly is one of the largest costs in a FLOW project due to the labour intensive, time consuming processes. Based on the port assessment, we have considered options for both steel and concrete substructure assembly activity to happen at Welsh ports.

4.1.1 Turbine

Table 7 summarises the cost breakdown for steel semi-sub assembly across the categories above.

Table 7: Port Activity Cost – Steel semi-sub substructure assembly

Steel Semi-sub Substructure Assembly	Units	300MW South Wales	1,000MW South Wales	300MW North Wales	1,000MW North Wales
Facility Cost	£m	19	39	19	39
Plant Cost	£m	63	143	63	143
Labour Cost	£m	56	127	56	127
Total	£m	138	309	138	309
Cost per kW	£/kW	463	310	463	310

- Port Talbot is assumed to undertake substructure assembly in both the South and North Wales case studies.
- There are some fixed costs associated with mobilising the site that make the 1,000MW site slightly cheaper on a 'per MW' basis than the 300MW site.
- Four to six substructures are expected to be manufactured simultaneously (in various stages of completion).

4.1.2 Concrete semi-sub

Table 8 summarises the cost breakdown for concrete semi-sub assembly across the categories above.

Table 8: Port Activity Cost – Concrete semi-sub substructure assembly

Concrete Semi-sub Substructure Assembly	Units	300MW South Wales	1,000MW South Wales	300MW North Wales	1,000MW North Wales
Facility Cost	£m	34	46	34	46
Plant Cost	£m	14	33	14	33
Labour Cost	£m	96	218	96	218
Total	£m	144	297	144	297
Cost per kW	£/kW	480	296	480	296

- Port Talbot is assumed to undertake substructure assembly in the South Wales case study; Mostyn is assumed to undertake the role for the North Wales case study. The costs are expected to be the same in both cases as the same equipment is used, much of it brought in for the project. Facilities costs may slightly differ between the two ports based on the area used and charges applied.
- The fixed costs associated with mobilising the site (Within facility costs) are expected to be higher for concrete assembly based on the requirement for an assembly line for the process, slipforming moulds, or other equipment that is set up for the entirety of the process. This also results in a larger benefit in scaling up operations to 1,000MW.
- There is expected to be two to three assembly lines with eight to twelve structures being constructed simultaneously (in various stages of completion).
- Plant costs are lower than for steel assembly, as there is expected to be reduced need for lifting equipment or SPMTs.
- Labour costs are broadly similar to the steel assembly

4.2 MOORING LINE AND ANCHOR STAGING

This is a much less labour-intensive process than substructure manufacture and has been modelled as the same process for either steel or concrete substructures. The South Wales case study site is both in deeper water and in a slightly harsher wave climate, resulting in mooring lines with longer chain or higher chain diameter. This impacts the cost of port facilities due to larger space requirements. **Table 9** shows a cost breakdown of port activity for mooring line and anchor staging.

Table 9: Port Activity Cost – Mooring line and anchor installation

Mooring Line & Anchor Installation	Units	300MW South Wales	1,000MW South Wales	300MW North Wales	1,000MW North Wales
Facility Cost	£m	1.3	2.8	0.9	2.0
Plant Cost	£m	0.6	1.4	0.4	1.0
Labour Cost	£m	1.7	3.8	1.2	2.6
Total	£m	4.0	8.0	2.0	6.0
Cost per kW	£/kW	12	8	8	6

4.3 TURBINE ASSEMBLY AND WET STORAGE

As with substructure assembly, there are some fixed costs associated with mobilising the site that make the 1,000MW site slightly cheaper on a 'per MW' basis than the 300MW site alongside the benefits associated with the learning rate.

The costs quoted exclude major investment required for the site to undertake substructure assembly contracts. This investment will likely be recouped over a series of projects at the port.

The 300MW project is assumed to be installed within a single season. The larger projects are expected to be manufactured over two seasons with some structures being stored in the waterway during the winter when weather conditions make hooking up the turbines at site infeasible.

Table 10 shows a cost breakdown of port activity for turbine assembly and staging for installation.

Table 10: Port Activity Cost – Turbine assembly and wet storage

Turbine Assembly (and wet storage)	Units	300MW South Wales	1,000MW South Wales	300MW North Wales	1,000MW North Wales
Wet Storage	£	0	2.5	0	2.5
Facility Cost	£	5	11	5	11
Plant Cost	£	9	20	9	20
Labour Cost	£	13	30	13	30
Total	£	27	61	27	61
Cost per kW	£/kW	91	60	91	60

The expectation that substructures will be stored for a period ahead of WTG installation adds a cost of £2.5 million to the 1,000MW case study. This cost has a high fixed component due to the mobilisation costs of bringing vessels in to hook up the substructures to temporary mooring lines, so this storage method is more appropriate for longer storage durations. Different solutions will be preferable depending on the expected duration of storage and facilities available at the port. Within the Milford Haven waterway, it may be preferable, and much cheaper, to moor a small number of structures along the quayside if it is for a short duration. A 'Just in Time' approach could be taken; however, it is not often preferred by project developers due to the additional risk of delay to turbines being operational.

4.4 LONG TERM PORT INVESTMENT TO REDUCE COSTS

As the case study is 'forward looking', there are underlying cost assumptions about minor outlay that each of the ports, or an EPCI using the port, will need to undertake to enable them to take on such projects. There are several areas that will benefit from visibility of a project pipeline and could achieve longer term cost saving by investing in more permanent infrastructure.

- Surface preparation may be required to level the ground at some ports. This is an expensive process. Depending on the area required, it can be as much as £5m. Visibility of a series of projects would support the investment case for the port and possibly allow them to recover cost over a longer series of projects, reducing costs for initial projects.
- In relation to ports that are identified as most appropriate for mooring line staging, the surface of the quay will need to be steel plated. It is likely that should a port wish to offer this service, it will be a dedicated area of the facility, so analysis in relation to the lifetime of the proximate project/s is required.
- A standardised modular access tower that works with a range of substructure designs that could be held by a port long term may accelerate port mobilisation and demobilisation and reduce costs associated with assembling bespoke structures for each project.
- Similarly, it would be beneficial for WTG OEMs to standardise lifting equipment for turbine components across different manufacturers, particularly if ports are expected to own and maintain such equipment.

4.5 ESTIMATED LOCAL CONTENT FOR PROJECTS

The pilot floating offshore wind projects deployed in the UK to date have had limited contribution from the UK supply chain, with major fabrication and installation works being undertaken in Spain and Norway.

Under the UK's Industrial Strategy and Clean Growth Strategy, there is an increasing need to demonstrate that public funding of energy generation is giving value to UK taxpayers and energy consumers. Currently the UK supply chain for bottom-fixed offshore wind is achieving 48% of the lifetime value of projects[8]. The Sector Deal, between the government and the sector, agreed in March 2019 sets a target of achieving 60% UK content by 2030, including an emphasis on increasing the UK share of capital expenditure ("capex") beyond 29%. This kind of supply chain development, which the region is seeking to encourage, will be critical to the sector delivering on its commitments.

4.5.1 Gross Value Added

Gross value added (GVA) is a measure of the value of goods and services produced in an area, industry, or sector of an economy. It provides a monetary value for goods and services that have been produced, less the cost of all inputs and raw materials that are directly attributable to that production.

To estimate the GVA, the activity has been mapped to established industry sectors. For each of these industry sectors, published Input-Output tables, GVA multipliers, average salaries and employment multipliers are available and have been used to estimate GVA and jobs based on the expenditure estimates in **Table 6**. This methodology is consistent with the methodology used for the Macroeconomic Benefits study[9]. The GVA is split into three parts:

- **Direct GVA** – The demand for relevant products and services that lead directly to creation of capital and labour income within the industry sectors.
- **Indirect GVA** – Consumption of goods and services produced by other industry sectors because of the primary activity, thereby leading indirectly to creation of capital and labour income within these indirectly affected industry sectors.
- **Induced GVA** – As wages and salaries (labour income) increase in line with increased output of industries, there may also be an induced effect leading to increased demand by households for goods and services.

8. www.renewableuk.com/resource/resmgr/publications/Offshore_Wind_Investment_V4.pdf
9. https://ore.catapult.org.uk/?industryreports=macroeconomic-benefits-of-floating-offshore-wind-in-the-uk

Direct GVA produced by port activity during the construction phase is shown in **Table 11**, estimated to be £68m - 72m for the 300MW case studies and £149m - £155m for the 1,000MW case studies. **Table 11** also shows total GVA (the sum of direct, indirect, and induced GVA) produced by port activity in each of the case studies. The 300MW case study generates between £160m – 166m through port activity in Wales and the 1,000MW project is estimated to generate between £345m - £358m, of which the substructure assembly is the largest component.

Table 11: Direct and Total GVA estimates.

Direct GVA	Units	300MW South Wales	1,000MW South Wales	300MW North Wales	1,000MW North Wales
Steel Semi-Sub Substructure Assembly	£m	56	126	56	126
Concrete Semi-Sub Substructure Assembly	£m	59	121	59	121
Mooring Line and Anchor	£m	2	3	1	2
Turbine Assembly (and wet storage)	£m	11	26	11	26
Total (Steel semi-sub)	**£m**	**69**	**155**	**68**	**154**
Total (Concrete semi-sub)	**£m**	**72**	**150**	**71**	**149**
Total GVA (Direct, Indirect & Induced)	Units	300MW South Wales	1,000MW South Wales	300MW North Wales	1,000MW North Wales
Steel Semi-Sub Substructure Assembly	£m	130	291	130	291
Concrete Semi-Sub Substructure Assembly	£m	136	280	136	280
Mooring Line and Anchor	£m	4	8	2	6
Turbine Assembly (and wet storage)	£m	26	59	26	59
Total (Steel semi-sub)	**£m**	**160**	**358**	**158**	**356**
Total (Concrete semi-sub)	**£m**	**166**	**347**	**164**	**345**

4.6 ESTIMATED JOB CREATION THROUGH PROJECTS

Table 11 shows a 'top down' estimation of direct jobs supported through the work at the port, based on Macroeconomic Benefits study[10] methodology. This forecasts 374 – 431 direct Full-Time Equivalent (FTE) job years created over the construction phase of the 300MW project and 834 – 902 for the 1,000MW project. An additional 308 - 357 jobs in indirect industries are also estimated for the 300MW project, and 692 – 747 indirect jobs in the 1,000MW project shown as the total jobs created in **Table 12**.

Table 12: Estimated job creation generated through port activity (FTE for one year duration)

Direct FTE	Units	300MW South Wales	1,000MW South Wales	300MW North Wales	1,000MW North Wales
Steel Semi-Sub Substructure Assembly	FTE	305	684	305	684
Concrete Semi-Sub Substructure Assembly	FTE	362	747	362	747
Mooring Line and Anchor	FTE	9	18	4	13
Turbine Assembly (and wet storage)	FTE	60	137	60	137
Total (Steel semi-sub)	**FTE**	**374**	**839**	**369**	**834**
Total (Concrete semi-sub)	**FTE**	**431**	**902**	**426**	**897**

10. https://ore.catapult.org.uk/?industryreports=macroeconomic-benefits-of-floating-offshore-wind-in-the-uk

Table 13: Estimated job creation generated through port activity (FTE for one year duration)

Total FTE (Direct, Indirect & Induced)	Units	300MW South Wales	1,000MW South Wales	300MW North Wales	1,000MW North Wales
Steel Semi-Sub Substructure Assembly	FTE	559	1,251	559	1,251
Concrete Semi-Sub Substructure Assembly	FTE	662	1,366	662	1,366
Mooring Line and Anchor	FTE	16	32	8	24
Turbine Assembly (and wet storage)	FTE	110	251	110	251
Total (Steel semi-sub)	**FTE**	**685**	**1,534**	**677**	**1,526**
Total (Concrete semi-sub)	**FTE**	**788**	**1,649**	**780**	**1,641**

4.7 IMPACT OF PORT STRATEGY ON LOCAL CONTENT

Using more than one port for the three key processes analysed does not necessarily mean diluting local content – it is entirely possible to use a combination of Welsh ports rather than having to look overseas.

For wind turbine staging, a key characteristic is the distance from the staging port to the wind farm itself. This is because the towing requirements for the fully assembled floating turbine are most stringent, and the weather windows for the final tow are the most restrictive. It could be disastrous to encounter a change in weather during that tow, so keeping the tow short in duration is crucial.

Distance from port to wind farm is usually a key factor for choice of an Operations & Maintenance (O&M) base. With floating wind, however, there is the option to tow a platform back to port for heavy lift operations. The port requirements for the kind of O&M that would require towing back to port are likely to be the same as for the wind turbine staging itself.

In terms of value, the pre-fabrication and assembly stages carry more value than the final turbine staging and so the goal should be to develop the required port facilities to attract these activities. However, for steel semi-subs at least, this may require significant capital investment. A logical first step towards capturing the whole value chain may be developing a very strong turbine staging offer, however this is likely to require the Celtic Quay development at Pembroke Port.

Having the final deployment stage, and the ongoing O&M activities based in Wales creates more rationale for having the higher-value earlier stage activities in the same locations, creating demand, and giving the signals for port owners to invest appropriately.

For concrete semi-subs, there is a much lower barrier to undertaking complete fabrication. Concrete construction is a capability with a broad industrial base in the UK and requires little investment in specialised equipment. However, as a technology, concrete semi-subs are less developed and demonstrated that the steel equivalent. Strategic incentives, such as grant-funded programmes, might accelerate development and acceptance of concrete foundations, which has the potential to enhance UK content.

5 CONCLUSIONS

It is clear from this analysis that no single Welsh port can currently handle all the activities required for deployment of a large floating wind farm. In north Wales, the recent R4 auctions make it clear that ports will have a focus on delivering services to the fixed bottom offshore wind sector, with a pipeline of projects over the medium to long term. For floating wind, however, there are two standout ports that could form the basis of a consortium of ports that has the current capability to deliver most of the required activity and which, with the necessary infrastructure investment could, in fact, deliver all the necessary activities.

Port Talbot, with its proximity to large steel-making facilities and having the necessary (existing and potential) space, appears the optimal Welsh port for floating substructure production, particularly for steel semi-sub scenarios. Port Talbot could be considered for supplying both South Wales and North Wales projects, and there are efficiencies in developing a single site to specialise in the activity, rather than developing two sites for the same purpose that may not have the long-term throughput to justify the upfront expense.

The Port of Milford Haven appears to be the optimal Welsh port for wind turbine staging. This is based on the assessment that the site has optimal channel depths and low average wind speeds, making for longer weather windows during which to undertake the turbine installation. The metocean conditions means there are also fewer limits on towage of final turbine platforms to deployment sites.

There are clear opportunities for other Welsh ports to make significant contributions to the other necessary processes involved in deployment of a floating offshore wind farm, notably mooring chain and anchor storage and deployment, and ongoing Operations and Maintenance (O&M). For the larger wind farms there will also be the need for wet storage of foundations which will require multiple locations around Wales.

To capture the maximum benefit from the FLOW value chain, significant investment in port infrastructure is clearly required. This has not been quantified in this report but needs to be better understood to understand potential cost premiums incurred by project developers and efficiently allocate financial support.A key enabler of such investment, missing at present, would be the existence of a credible pipeline of projects to be developed over the next 20 years. At present, project developers can only approach The Crown Estate (TCE) for 'development' projects of a capacity up to 100MW, and there is no timetable for auctions for leases of seabed areas for floating wind. Discussions with potential project developers indicate that there is immediate appetite for development rounds of at least 300MW, and that there is credible short-term appetite for commercial leases for wind farms of at least 1GW capacity.

Another barrier to capturing the full FLOW value chain is the lack of large fabrication facilities for steel semi-subs. This issue would largely disappear if concrete semi-subs became a standard for FLOW.

6 RECOMMENDATIONS

- **Recommendation 1.**
  A key requirement in attracting FLOW developers to use local ports is the existence of large areas of laydown space, and adjacent areas suitable for manufacturing. It is recommended that Welsh Government explore how ports can be incentivised to invest in and create laydown space in advance of projects reaching investment decisions. Welsh Government involvement in such incentives would also send a strong policy signal to developers that FLOW projects will be supported in other ways.

- **Recommendation 2.**
  While it is unlikely that, even with significant investment, any single Welsh port could support delivery of a large FLOW project, this report has shown that a consortium of ports could support such project delivery, and we believe that there is appetite for Welsh ports to collaborate and share the FLOW value chain. It is recommended that Welsh Government should consider whether appointing a 'Ports Coordinator', or a similar approach, might smooth the way to such collaboration.

- **Recommendation 3.**
  We recommend that engagement between all stakeholders and TCE be stepped up, to ensure the TCE is fully aware of the potential for rapid project development in the Celtic Sea and is aware of the pressing need for an auction round(s) to enable such developments, and hence provide a pipeline of projects that can help support investment decisions to upgrade and extend Welsh port capabilities.

- **Recommendation 4.**
  Welsh Government should consider how it could incentivise the uptake of concrete semi-subs by the FLOW industry, as this would significantly reduce the barriers to full foundation fabrication being carried out in Welsh ports. Actions could include:

  - A Small Business Research Initiative (SBRI) approach from either Welsh Government, UK Government or both, leading to the procurement of a concept design, followed by procurement and testing of a prototype foundation.
  - A project in conjunction with the Floating Offshore Wind Centre of Excellence, to exlore and demonstrate concrete foundation concepts.
  - A Europe-wide, Horizon Europe funded project.

- **Recommendation 5.**
  It is known that several Welsh ports have the potential to increase working land available by gaining access to contiguous or nearby spaces that are under other ownership. This report has not been able fully to explore this opportunity. We recommend that Welsh Government consider a follow-on piece of work to gain better insights to this issue. This could potentially be part of Recommendation 2.

- **Recommendation 6.**
  Alternative, innovative approaches to enhancing port capabilities should be fully explored. Flexible temporary or floating solutions may complement existing facilities to support local construction activity in a cost-effective way with a shorter lead time. Further analysis of the constraints may highlight areas where these options could work alongside port development over the long term. As with Recommendation 4, a SBRI approach could allow Welsh Government to procure a novel floating dry dock solution that could be used as a short term solution for small, early floating wind projects (Erebus, Valorous) without disrupting longer term infrastructure developments in the ports.

- **Recommendation 7.**
  A comparison of the full-life carbon content of steel and concrete semi-subs has not been carried out. We recommend that Welsh government investigates this issue before making any decision on which material, if any, to prioritise.

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