renewableUK

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Floating Offshore Wind Taskforce: Industry Roadmap 2040

Building UK Port Infrastructure to Unlock the Floating Wind Opportunity

Report produced by: Royal HaskoningDHV Enhancing Society Together

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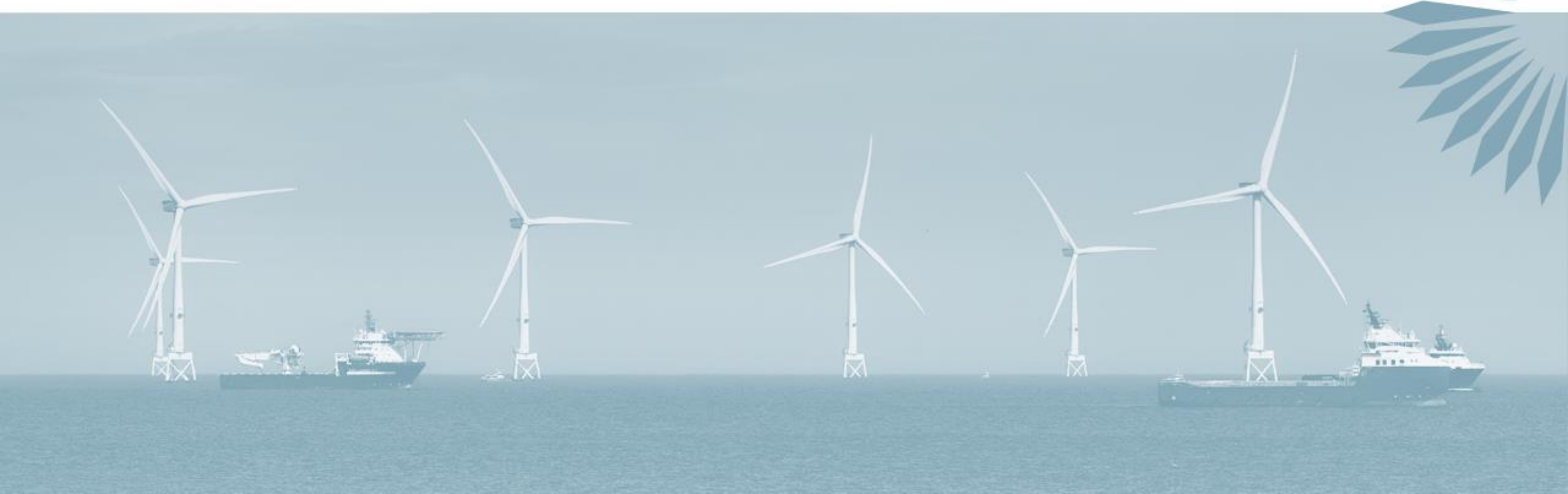


The aim of the roadmap is to provide guidance on the port capacity and capabilities, supply chain development options and must-have investments required to reach FLOW ambitions

Introduction

Floating offshore wind (FLOW) will play a critical role in the UK's decarbonisation and energy security ambitions. Its position as the world leader in offshore wind, coupled with the largest pipeline of commercial FLOW projects in the world, means the UK is well placed to scale up and commercialise this technology. With the objective to drive down the cost, de-risking the journey to net zero as well as delivering significant economic benefits. **However, progress will be impeded unless significant development takes place in UK-based port facilities and the supply chain.**

RenewableUK and the Offshore Renewable Energy Catapult (OREC) have worked with the UK, Scottish, and Welsh Governments, Northern Ireland Executive, leading offshore wind and industry companies and other key stakeholders to establish the Floating Offshore Wind Task Force (FLOW TF).

The FLOW TF will ensure the UK stays at the forefront of this cutting-edge technology by helping accelerate the development of this industry that is expected to create thousands of jobs and attract billions of private investment. **The vision is to maximise the benefit of this industry to the UK and to export UK-based technology and expertise around the world.**

RenewableUK has selected Royal HaskoningDHV to develop a port industry roadmap, which was undertaken in two stages. **The first phase report** was delivered in January 2023 and focused on identifying critical port infrastructure requirements that are needed for a set of deployment scenarios. These requirements were then compared to the UK's current port infrastructure to evaluate the capability gap and the potential port development options. It also established the principal government and industry interventions in the FLOW supply chain, including the Floating Offshore Wind manufacturing investment Scheme (FLOWMIS). All the output from this first phase report is used as input for this integrated roadmap report.

The second stage is the delivery of this integrated roadmap. This roadmap builds further on the results from the first stage port report by adding the broader industry and supply chain context while providing more granularity to the industry programme, recommendations and required interventions. The integrated roadmap also identifies the economic benefits resulting from both accelerating FLOW deployment and investing in key port and supporting infrastructure.

Aim of the Floating Offshore Wind Taskforce

The FLOW TF aims to direct future strategic decision-making, prioritisation and investment to support the deployment of FLOW in UK waters alongside the development of local supply chains and necessary infrastructure. As mentioned, this report identifies the principal UK port infrastructure requirement for FLOW and the likely investments and interventions that are needed to achieve the deployment scenarios.

FLOW deployment requires very different port facilities to conventional shipping and port use and therefore the timely development of bespoke port infrastructure will be critical to the success of the industry. Clear guidance on the required port capacity and capabilities, strategic port and supply chain development options, as well as a sequence for timely must-have investments and follow up research from both regional and national perspectives, will be provided within this roadmap.

Approach

To establish a FLOW roadmap up to 2040, a stepped approach was taken to assess the industrialisation requirements for FLOW and its associated port infrastructure and supply chains:

- **Step 1: Establish deployment scenarios** based on the "aspired high case" scenario of 5GW by 2030 and an extrapolated scenario of 34GW in 2040. This forms the basis of the main question of this report: *What industry developments and port infrastructure do we need to develop to reach our deployment ambition*?
- **Step 2: Technology assumptions** were established with industry experts and stakeholders. This revealed there remains a multitude of technology and deployment concepts still being developed, but a representative set of design parameters for ports could still be developed for the purpose of this study.
- **Step 3: An assessment of the value chain and more in-depth role of ports** was carried out, with an overview of current UK port and supply chain capabilities. Potential gaps and bottlenecks were then identified to inform a series of challenges, conclusions and interventions.
- **Step 4: Investment requirements and economic benefits analysis** was executed in which the deployment scenarios are combined with estimated port intervention cost. This delivers an indication of the potential economic value and UK job creation.
- **Step 5: Proposal for an industry programme for port developments** which concludes on key interventions, strategic options, enablers and considerations to support the development of port infrastructure for FLOW deployment in the UK.

Ports are a crucial part of the FLOW value chain but are currently experiencing difficulties in developing FLOW infrastructure due to uncertainty and a supply chain that still needs to materialise.

Role of ports

FLOW projects are manufactured, installed and operated using a diverse value chain of fabricators and suppliers, port facilities and installation assets. Ports play a critical role in determining both the technical and commercial viability of FLOW deployment in a region and enable realisation of economic benefits.

Port requirements for FLOW

- **A combination of manufacturing, assembly, integration and Operation & Maintenance (O&M) ports in regional or national proximity will be needed** to facilitate supply, service installation and provide O&M throughout the FLOW asset lifetime.
- **Integration ports are essential to any gigawatt scale market development**. They should be optimally located in proximity of projects and have adequately sized facilities with access channels, berths and land areas that can handle FLOW integration on an industrialised scale.
- **Steel substructure assembly ports and concrete substructure manufacturing ports will need large land areas to construct and assemble FLOW substructures** in industrialised production lines.
- The basic port infrastructure requirements for concrete manufacturing and steel assembly are considered to be relatively similar. **Therefore, common port infrastructure that is technology agonistic should be developed on a no-regret basis**, with final modifications or conversion available to support the dominant substructure type as FLOW evolves. Close project proximity of these sites is less critical but securing on a national basis would improve supply chain efficiencies and secure supply.
- **The role and feasibility of wet storage and adequate crane solutions is still being established**, but they are both expected to be a key consideration to optimise efficiency and investment, as well as installation cost trade-off decisions.
- **Ports will play a significant role in enabling the import, handling and deployment of FLOW moorings, anchors and array cables.** While the scale of this opportunity will be considerable, it is expected that existing UK port facilities can be adapted more easily to meet these requirements.

Challenges

- Key challenges are the **current port infrastructure limitations** with respect to the widths and depth in access channels and at berths, availability of landside area, and required crane capacity.
- **The absence of standardisation, as well as uncertainty, and the current project-by-project approach** to port facilities is hindering the port infrastructure business case and deterring investments.
- **Large scale FLOW will also require a significant increase in the required workforce and new skills**. This creates both opportunities and challenges to employment, but also fosters the possibility to transition skills found in existing industries into FLOW.

Supporting FLOW Supply Chains

This roadmap focuses on the most critical activities in the supply chain linked to port infrastructure, substructure manufacturing/assembly, FLOW integration and offshore installation activities.

Manufacturing and fabrication

The FLOW supply chain is currently characterised by multiple reputable wind turbine Original Equipment Manufacturers (OEMs) and global suppliers. The expansion of UK manufacturing and fabrication will depend on market demand, both domestically and from cross-border opportunities, as well as the ability to develop competitive, standardised and innovative production. **Attracting OEMs and suppliers of key components will be beneficial to cost levels, technical feasibility and acceleration of FLOW deployment.**

Ports will benefit too because it strengthens their competitive position as transporting hubs in the value chain, and supports the business case for developing infrastructure to accommodate FLOW activities. **To ensure these opportunities are captured, it is critical that developers; suppliers; ports; and the UK government take a proactive joint approach to strategic development of FLOW production.**

The development of FLOW substructure production facilities will optimise and secure supply for ports to the benefit of UK's FLOW pipeline, particularly as demand and competition is expected to boom on the back of global offshore wind growth expectations. Without support these facilities are unlikely to emerge on a merchant basis before 2030.

To be able to build up capacity and supply chains in the UK, standard modular and industrialised processes servicing multiple substructure designs have to emerge, enabling components to be mass produced at multiple locations. Requirements and infrastructure related to substructure manufacturing and assembly need to be considered when developing ports.

Vessels

To secure the necessary fleet of vessels required for the installation and O&M of FLOW, further development of existing technology solutions and assets will be necessary. As demand and scale increases, it is anticipated that next-generation vessels will be built with a dedicated focus on this purpose.

We do not anticipate a structural shortfall in overall availability or capacity of vessels required for deployment (e.g. anchor handling vessels, service operation vessels). However, **during periods of peak demand, access to specialised vessels (e.g. cable laying vessels) could be a challenge**, especially given the anticipated increase in fixed-bottom and FLOW developments. However, since offshore construction and shipbuilding industry is primarily driven by global supply and demand, securing vessel capacity for the UK is limited and it should therefore focus on the creation of a strong, predictable and accessible UK-based FLOW markets.

Investment of up to £ 4bn in integration and manufacturing/assembly ports are required to reach UK's FLOW ambition, with benefits being significantly greater than the cost.

What UK ports need to enable FLOW deployment

- Reaching the Government's FLOW target of 5GW in 2030 and accelerating deployment to an industrial scale at 34GW in 2040 can only be achieved if access to FLOW port infrastructure and supply chains is available in the UK.
- **The UK does not currently have the required port infrastructure to unpin industrialised scale FLOW deployment.** There are currently no port facilities identified regionally or nationally that fulfil the infrastructure requirements for an industrialised scale integration, substructure assembly or manufacturing facility based on the technology expectations set out in this report. Developing UK port facilities is critical to accelerate the deployment of FLOW and maximise the socio-economic opportunities. Besides domestic FLOW deployment and benefits, the export opportunities and synergies with fixed-bottom offshore wind should be considered when developing these port facilities.
- **Timely investment in port infrastructure development is required to ensure ports are fully prepared by 2028-2029 to support industrialised scale deployment of FLOW in the 2030s**. The timeline towards 2030 is tight and it seems challenging to deliver on our ambition if prompt action is not taken, and port planning and consenting uncertainties are not minimised.
- Approximately **fifteen UK port locations** have been assessed which, with varying degrees of investment, could be developed to provide industrialised scale integration, assembly and manufacturing facilities to support FLOW deployment in the UK.
- In the initial stages of deployment, **integration ports are likely to be near floating projects** in the Scottish or Celtic Sea. **Ports outside these regions, but still within the UK, could be positioned as steel assembly ports, concrete manufacturing** or other specialist supply and support **ports**.
- The expected FLOW capacity development from Scotwind in combination with the strong level of available infrastructure in the region **provides Scotland with the opportunity to develop ports into combined integration and manufacturing/assembly facilities.** Land area availability seems to be the main limiting factor in developing industrial scale FLOW ports.
- Celtic Sea developments are at an earlier stage of commercial maturity, with its first offshore wind leasing round ongoing through 2023. **Deployment in the Celtic Sea region is initially expected to be lower than ScotWind, but the region is expected to develop several ports capable of supporting FLOW in the near future, with the right investments**.
- The assessment shows that projects in **Scottish waters require 3 to 5 integration ports while the Celtic Sea requires 2 integration ports by 2030**. In addition, at least **4 ports are required to service steel assembly and/or concrete manufacturing for FLOW**, with the configuration of these ports being dependent on the direction of substructure technology.
- **Clarity and alignment on port requirements and design envelopes** is likely to give a boost to required developments. Common industry practices and design requirements could be jointly established to allow appropriate port infrastructure to be developed and optimised.
- Detailed **studies to identify the best strategy, approach and potential wet storage locations** around the UK whilst joint industry **research on cranage requirements, options, innovations and finance** seem required.

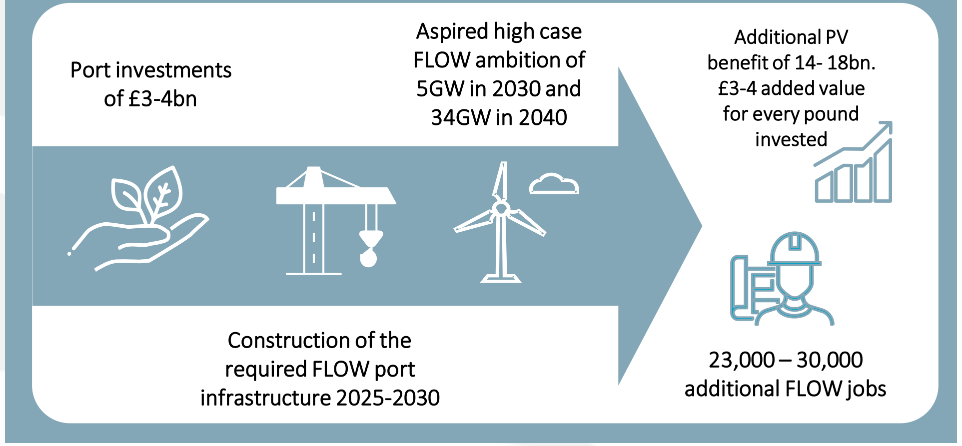
Economic benefits and job creation

There is no doubt that deploying FLOW at an ambitious level towards 2040, accompanied with the required port infrastructure development, will generate significant economic value for the UK.

Reaching the aspired FLOW deployment scenario will require substantial investment in port infrastructure adjustments and expansion over time. Developing the total 5-7 integration ports and 4-6 substructure manufacturing/assembly ports identified in this report will require up to **£4bn in port construction investments**.

The Present Value (PV) benefits of investing in ports are significantly greater than the costs at **£14-18bn** between 2023 to 2040. This means the UK would generate approximately **£3.4 to £4.3 of added value to the economy for every £1 invested** in port facilities to support the FLOW sector.

Compared to the business-as-usual case, achieving the aspired high case scenario supports around **23,000 – 30,000 additional FLOW jobs** in the UK. By 2040, the FLOW sector will support a total of **45,000 jobs** across the UK, **with about 35% representing employment in FLOW operation.**



Port investments of £3-4bn

Aspired high case FLOW ambition of 5GW in 2030 and 34GW in 2040

Additional PV benefit of 14- 18bn. £3-4 added value for every pound invested

Construction of the required FLOW port infrastructure 2025-2030

23,000 – 30,000 additional FLOW jobs

FLOW Port infrastructure requires collaboration for strategic planning to develop infrastructure requirements, common build strategies, investment approaches and supply chain activities.

Recommendations

In order to develop and scale port infrastructure in time to facilitate the FLOW ambition of up to 5GW by 2030 with a view to this report's modelled deployment of 34GW by 2040: A collaborative programme needs to be taken forward in the UK to jointly develop FLOW port infrastructure. We advise that this should contain and detail the following interventions, investments and investigations:

Port development recommendations

Advance a multi-port strategy and regional clusters of ports for the 2030 deployment ambition in the upcoming years, supported by a value proposition that emphasises wider economic gains, commercial upsides and synergies for ports.

Focus on how to develop basic port infrastructure for 3 to 5 integration ports in Scottish waters, 2 integration ports for the Celtic Sea, and a minimum of 4 manufacturing and assembly ports. This can be based on identified common requirements and no-regret facilities, and should commence in 2023-2024.

Establish a minimum agreed threshold of port infrastructure to help the FLOW market anticipate available port capacity for project timing and fitting technology choices. This will provide more clarity on what ports can handle at what point in time, supporting smoothening and certainty of deployment while creating a stronger business case to gradually expand infrastructure as the market scales.

Target port design envelopes with common build strategies through structural cross-industry collaboration. Focused industry collaboration groups should be set-up and structured in 2023-2024 to provide agreed port infrastructure requirements as part of the strategic port approach.

Additional industry research is to be carried out in 2023 to identify the wet storage requirements, the scale of the issues and identification of sites, cross-border opportunities and export potential, skills and workforce requirements, as well as the deepening of long-term financial support requirements and options.

Set up a structured national collaboration between groups of FLOW developers and port authorities that should focus on **jointly identifying, developing and sharing port infrastructure facilities; and mobilising and bundling private and public funding in a strategic investment approach.** Preferably this is an open and transparent group which takes a holistic approach to gasp the potential synergies with other port activities.

Supply chain development recommendations

The UK FLOW ambitions would benefit most from the development of competitive manufacturing and fabrication facilities for FLOW substructures. Early development would accelerate deployment; create a strategic advantage by setting production standards; secure supply for UK ports and projects; improve efficiency and price certainty in the value chain; and create export opportunities for industry and ports.

Further investigation into the feasibility and benefit of developing concrete manufacturing and steel assembly as viable solutions in the UK. For concrete manufacturing this means getting a better understanding of the feasibility, infrastructure requirements and UK's potential for concrete construction. For steel, this entails additional research to assess the feasibility and competitiveness of highly modular and standard based steel substructure fabrication in the UK.

Proactively attract and develop strategic supply chain activities related to mooring; cable; tower manufacturing and fabrication; and installation vessels will improve the UK supply chain and subsequently generate efficiency, economic value and secures supply for UK FLOW projects. **Healthy demand and predictability of pipelines, coupled with freeports that will attract industry investment and create FLOW clusters, will improve attractiveness to locate within the UK.** The introduction of non-price based criteria within leasing rounds that focus on building up local supply chains could be jointly established to priorities early stage development and improve port business cases.

FLOW sector support and development recommendations

A **continuous or recurring financial support scheme should be in place with a more mission driven investments focus and the aim to secure both public and private funding.** Investment support could focus on unlocking public infrastructure development bank funds, connecting (regional) public-private investments, linking transport infrastructure investments by considering network effects, and by assuring or underwriting revenue streams over time.

Planned visibility over long term deployment and sequencing of FLOW construction, while maintaining competition, is necessary to identify supply chain utilisation over time. More centralised planning or guidance for the timing of projects, based on public-private collaboration, improves market certainty.

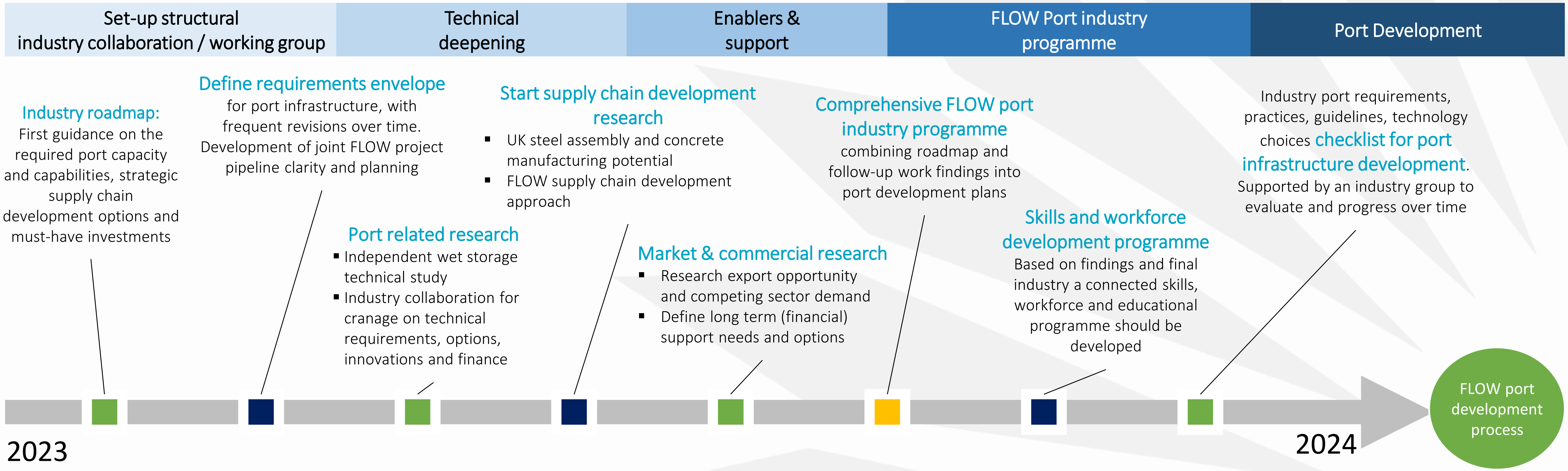
The GVA analysis shows that the UK could benefit in terms of economic value and job creation. However, scarcity of skills and workforce should be identified and addressed early on. **Early identification of the required workforce and skills** to develop, scale and operate port infrastructure with a supportive manufacturing supply chain **is essential in developing an adequate skills and workforce programme.**

Suggested follow-up work consists of jointly answering remaining technical and development issues, which could feed into the FLOW port industry programme.

Short-term agenda

This report has set out a first comprehensive view on the initial FLOW port requirements, infrastructure and industry gaps, and suggests potential interventions, approaches as well as the follow-up work that is required. Based on the outcomes of this report we have established suggestions for follow-up work in 2023.

These actions give further guidance on joint industry key focus areas, the remaining knowledge gaps that need to be filled, and the sequence of actions to stimulate FLOW port infrastructure developments in the right direction at the right time.



Set-up structural industry collaboration / working group

Technical deepening

Enablers & support

FLOW Port industry programme

Port Development

Industry roadmap: First guidance on the required port capacity and capabilities, strategic supply chain development options and must-have investments

Define requirements envelope for port infrastructure, with frequent revisions over time. Development of joint FLOW project pipeline clarity and planning

Port related research
- Independent wet storage technical study
- Industry collaboration for cranage on technical requirements, options, innovations and finance

Start supply chain development research
- UK steel assembly and concrete manufacturing potential
- FLOW supply chain development approach

Market & commercial research
- Research export opportunity and competing sector demand
- Define long term (financial) support needs and options

Comprehensive FLOW port industry programme combining roadmap and follow-up work findings into port development plans

Skills and workforce development programme Based on findings and final industry a connected skills, workforce and educational programme should be developed

Industry port requirements, practices, guidelines, technology choices **checklist for port infrastructure development**. Supported by an industry group to evaluate and progress over time

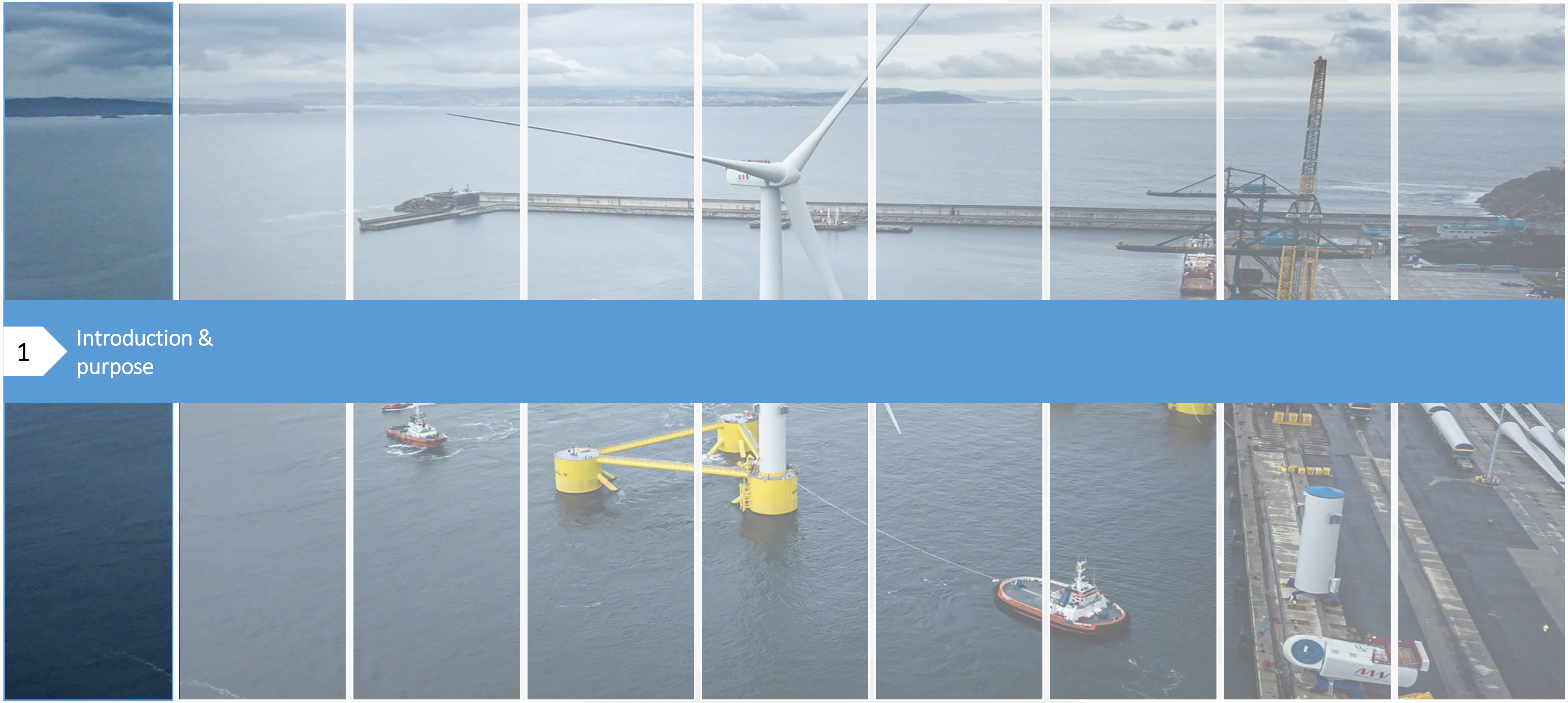
2023

2024

FLOW port development process

Report content

1	Introduction & purpose	**Explaining the reason, context, value and purpose** of the Building UK Port Infrastructure to Unlock the Floating Wind Opportunity report.
2	Scenario, assumptions & scope	**Established deployment and technology scenario 2040**, including a description of the FLOW value chain for report scoping.
3	Port roles and requirements	**Identifying the type of ports and their requirements** for the deployment of the envisioned FLOW technology
4	Port infrastructure gap	**Assessment of the UK port sector** and identifying the gap with required port infrastructure capacity and capabilities
5	Port strategy, planning and timeline	**Port strategy options and port planning actions** to deliver on the deployment timeline
6	Supporting supply chain: Manufacturing and fabrication	**Assessment of the UK FLOW supply chain dynamics** and the potential development focus to support port infrastructure developments
7	Supporting supply chain: Vessels	**Assessment of the FLOW vessel spread, market dynamics** and port requirements and focus to stimulate FLOW deployment
8	Interventions and economic benefits	**Formulating critical interventions and must-have investments**, translated into **economic added value of port investments** that assure FLOW deployment ambitions
9	Recommendations and considerations	**Overall report conclusions**, recommendations key considerations and follow-up work
10	Appendix / supporting deliverables	A. Port types & requirements B. Regional port and manufacturing assessment C. Port interventions and GVA methodology D. GVA results and sensitivities E. Supporting documents & Sources



1 Introduction & purpose

Image source: GWEC

The FLOW Task Force Industrialisation Roadmap aims to direct future strategic decision-making, prioritisation and investments to support the development of FLOW in UK waters

The Floating Offshore Wind Taskforce

RenewableUK (RUK) supports over 450 member companies to ensure increasing amounts of renewable energy are deployed across the UK and to access markets to export all over the world. RUK and the Offshore Renewable Energy Catapult (OREC) have worked with the UK, Scottish and Welsh Governments and Northern Ireland Executive to establish the Floating Offshore Wind Taskforce (FLOW TF) to ensure that the UK stays at the forefront of this cutting-edge technology, creating thousands of new jobs and attracting billions in private investment.

This FLOW Taskforce consists of leading companies who are operating and developing floating projects around the UK, senior representatives from the UK and devolved Governments and key stakeholder organisations. Its vision is to ensure the UK maximises the benefits of this burgeoning industry by capturing significant market share not only in the UK but also by exporting technology and expertise around the world.

The objective of the FLOW TF is to define the enormous scale of opportunity for the industry and to produce a comprehensive report on how to make the most of this, which was undertaken in two stages:

1. The first stage, which concluded in January 2023, focused on identifying critical port infrastructure needs that are required to deploy the government's ambition of 5GW by 2030. The findings were submitted to the Department for Energy Security and Net Zero (DESNZ) to inform government and industry interventions in the FLOW supply chain, including the Floating Offshore Wind manufacturing investment Scheme (FLOWMIS).
2. This second phase integrated report builds further on these results and adds the broader industry and supply chain context and gives more granularity to the recommendations and interventions. The integrated roadmap also provide the first calculation of the benefits resulting from both accelerating FLOW deployment and investing in key port and supporting infrastructure.

Purpose of the roadmap

The Industrialisation Roadmap aims to direct future strategic decision-making, prioritisation and investments to support the development of FLOW in UK waters. The goal is to stimulate and accelerate the deployment of FLOW in line with the targeted ambition of 5GW by 2030, with the development of the UK supply chain and investment in necessary infrastructure.

As ports are seen as critical infrastructure this report aims to set a clear guidance on the required port capacity and capability need, port and supply chain development strategies. The main focus of the roadmap is on defining must-have infrastructure investments and industry interventions from a regional and national perspective to assure targeted FLOW ambitions can be met.

This roadmap supports UK's need to secure more energy from renewable sources and seize opportunities of net zero, as strategically targeted by the newly formed DESNZ.

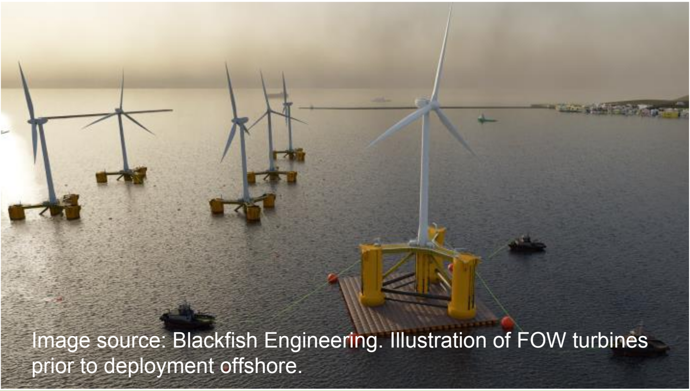


Image source: Blackfish Engineering. Illustration of FOW turbines prior to deployment offshore.

Source: RUK, EnergyPulse Insights, RHDHV, Opergy, ORE Catapult

FLOW will be a critical enabler of the UK's energy security and net zero ambitions. Grasping the FLOW opportunity will require a ramp-up in domestic supply chain, ports, vessels, and workforce.

Setting out the case for FLOW

To date, offshore wind developments in the UK have primarily focused on fixed-bottom wind, especially off the East coast and in the Irish Sea. Fixed-bottom foundations can only be used in shallow waters of depths up to 50m, limiting access to stronger and more reliable winds found in deeper waters. FLOW can unlock wind generation further offshore in rougher conditions, significantly increasing the potential for wind generation.

Given that 80% of the world's potential offshore wind resources is in deeper waters[1], FLOW will be a critical enabler of the UK's energy security and net zero ambitions. Moreover, since the Climate Change Committee estimate that over 100GW of offshore wind is needed by 2050[2], this is only technically feasible if we develop FLOW at large scale.

Fortunately, the UK is also in a strong position to be a global leader in FLOW, with several early-stage operational FLOW windfarms, such as Kincardine and Hywind, and a healthy pipeline of both fixed and floating projects, with the latter totaling 37GW according to RenewableUK's EnergyPulse. **The Government has also signaled its support for FLOW with an ambition of up to 5GW by 2030, viewing the technology as critical to the country's energy transition away from fossil fuels and an opportunity for economic growth and new jobs.**

Sustainable cost reduction

To deploy FLOW at the scale needed to reach net zero, it is crucial to mitigate risk and decrease costs to a point where subsidies are no long necessary – a "subsidy free" level.

Early testing and demonstration-scale projects have observed costs falling substantially as the technology matures and increases in scale. For example, Hywind Scotland costs fell by 70% between the commissioning of its pilot in 2009 (2.3MW) and full-scale project in 2017 (30MW). Additionality, Hywind set a record high average annual capacity factor of 57%, which is significantly higher than the average for fixed foundation projects.[3] As the UK builds more FLOW projects in the windiest locations further from the shore, we are expecting to see high load factors of 60% or more in the projects being planned.

The main driver of cost reduction for FOW in the short and medium term is scale of deployment. Therefore, the UK need to ensure we rapidly ramp up deployment in the coming years by developing and delivering a strong and steady pipeline of FOW projects from 2030 to deliver the scale of deployment needed by 2050, whilst minimising the cost of delivering this.

Furthermore, visibility of, and the delivery of, a strong steady pipeline of FOW projects is critical to the cost-effective delivery of projects. This will unlock the required investments in ports and supply chain capability and capacity, increasing UK GVA.

Innovation will also play a key role in reducing the cost of FOW in the medium and long term directly (reducing CAPEX/OPEX) and indirectly (reducing risk, cost of capital etc). Delivering that requires innovation investment in the short term in the UK supply chain. This will play a critical role in ensuring the UK supply chain maximises the opportunity associated with FOW, maximising UK GVA from UK and international FOW markets.

Image source: Equinor - The Hywind Scotland floating wind farm. (Photo: Øyvind Gravås / Woldcam - Statoil ASA)

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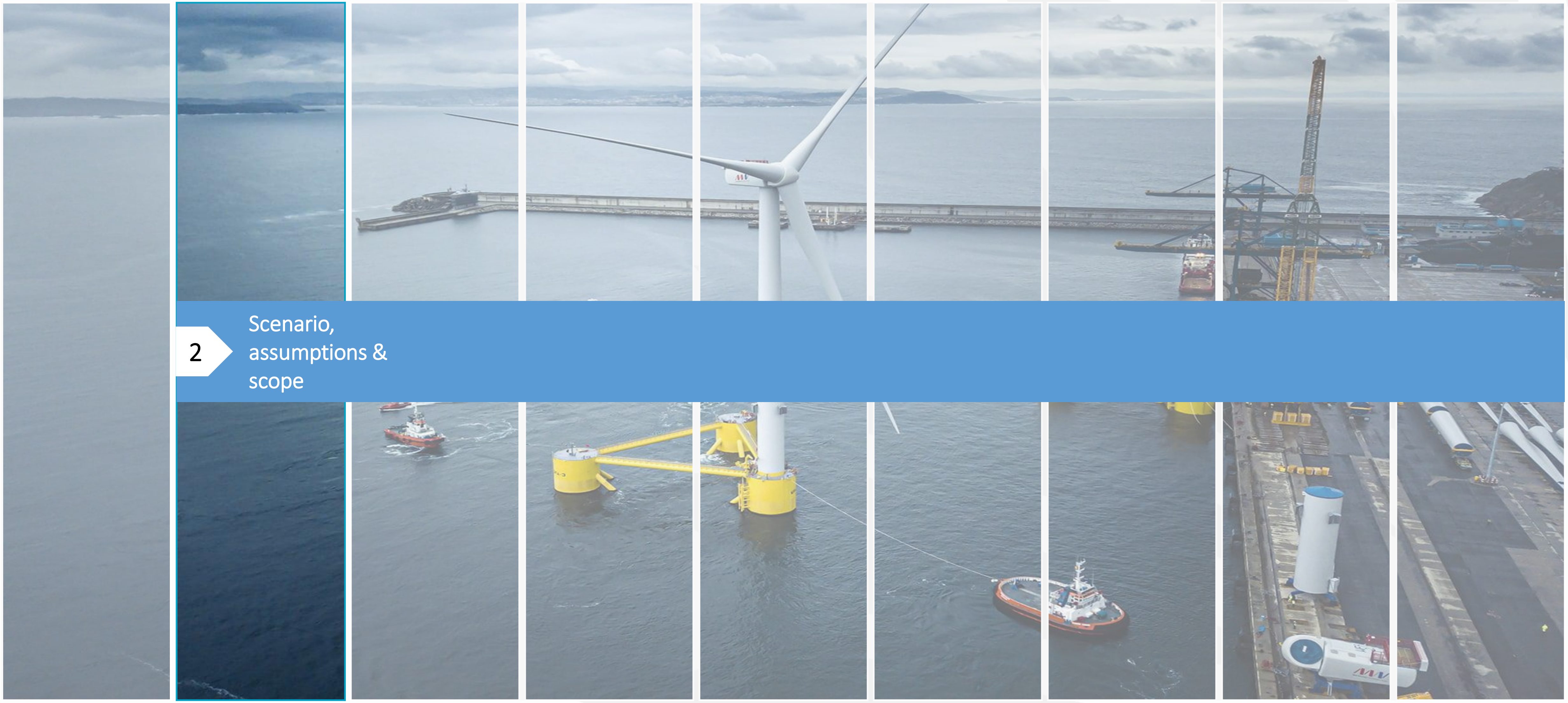
1) GWEC March 2022 "Floating Offshore Wind – a Global Opportunity"
2) UK's Climate Change Committee December 2020 "Sixth Carbon Budget"
3) Equinor, "Hywind Scotland remains the UK's best performing offshore wind farm"
4) FLOW TF by ORE Catapult in 2020: "Floating Offshore Wind – Cost Reduction Pathways to Subsidy Free".



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Scenario, assumptions & scope

Image source: GWEC

Deployment scenarios have been established to define a baseline directed at the necessary infrastructure to enable timely deployment of FLOW at an aspired high growth ambition

Deployment scenario methodology

As a first step in the process of developing scenarios for the required port capacity, **RHDHV and ORE Catapult have established deployment scenarios specifically for this study**.

These deployment scenarios have been based on the most recent guidance from the Climate Change Committee's (CCC) Sixth Carbon Budget, which outlines a range of options for a net zero energy system. **The CCC's pathways have been used as the primary reference for the scale of offshore wind the UK might seek to deploy by 2050 to meet net zero.**

Based on the work of the CCC, ORE Catapult have maintained a set of credible deployment scenarios which see an aggregate installed capacity of 75GW (low), 100GW (base) and 150GW (high) of offshore wind by 2050. **These deployment scenarios from ORE Catapult contain the annual and cumulative expected deployment of both fixed bottom offshore wind and FLOW.**

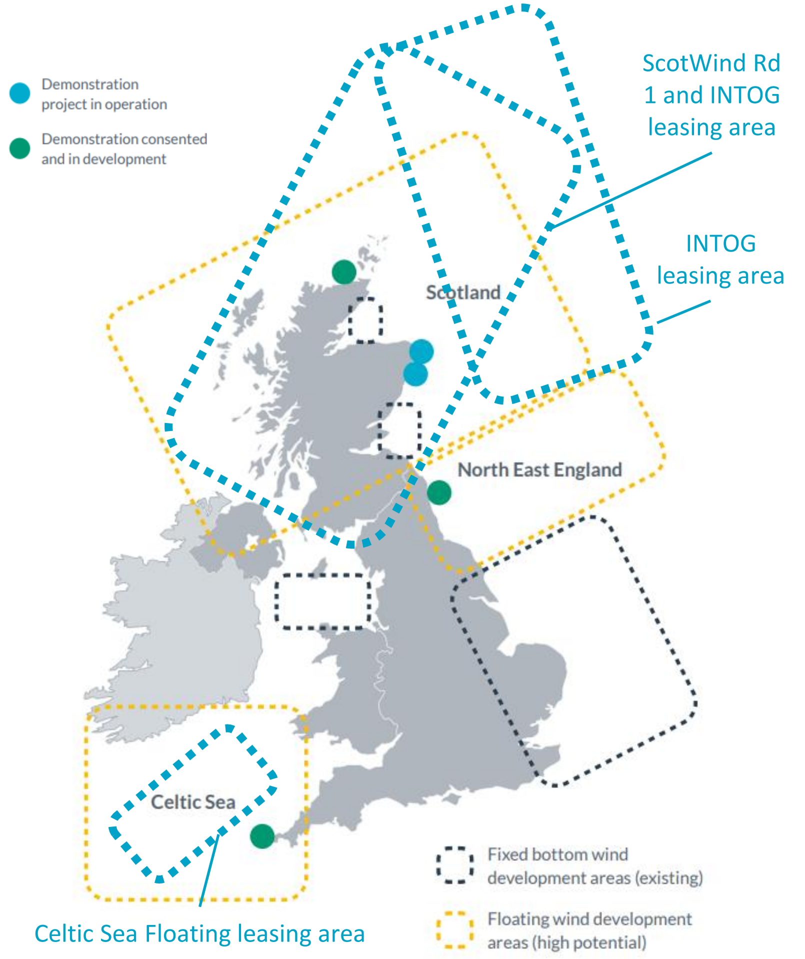
In order to determine the deployment scenario for this report, a blend of bottom up (project based) and top down (trends and targets) assumptions have been used, while considering the targeted ambition of 5GW in 2030. **This has resulted in a so-called "aspired high case" of 5GW in 2030 and 34GW in 2040 - which is used as the main scenario for this study.**

The deployment scenario analyses are available in a separate document and includes regional profiles, market expectations and a 2050 extrapolation for Scotland (incl. INTOG) and the Celtic Sea. Throughout this process the experience of ORE Catapult has been used and FLOW stakeholders have been engaged.

Northern Ireland

- The deployment scenarios exclude the deployment in North East England and Northern Ireland. Although these regions have significant long-term potential, there is high uncertainty on deployment levels and developments are considered too early-stage to translate these into an adequate 2040 scenario of port and industry interventions for the scope of this research.
- Nonetheless, important progress has been made in Northern Ireland. The Energy Strategy for Northern Ireland, launched in December 2021, established a renewable electricity consumption target of 70% by 2030 which increased to 80% by 2030 by the Climate Change (Northern Ireland) Act 2022. The Energy Strategy also established a commitment to diversify the renewables generation technology mix, with an initial focus on offshore wind and marine renewables.
- To deliver on the Energy Strategy, the Department for the Economy (DfE) published its intention to develop an action plan to deliver 1GW of offshore wind in the Energy Strategy Action Plan 2022 (published 16 January 2022). Over the course of 2022, DfE led the development of the Draft Offshore Renewable Energy Action Plan (OREAP), taking the first steps towards delivering on the Energy Strategy commitments. The Draft OREAP sets the direction to deliver 1GW of offshore wind from 2030, and aims to accelerate that ambition where possible.
- Northern Ireland currently has 2-2.5GW in announced pre-planning pipeline, which need to go through a competitive leasing round. The announced early stage floating wind projects in Northern Ireland are North Channel Wind and Simply Blue Group's Olympic and Nomadic.

FLOW deployment scenario scope of the roadmap



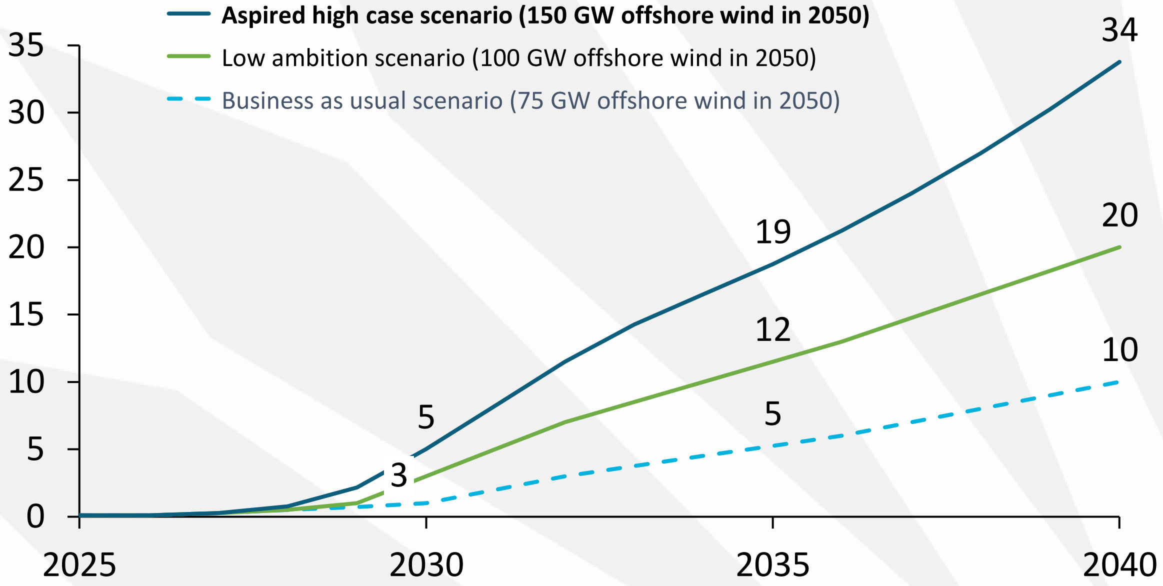
Source: ORE Catapult, RHDHV – Deployment scenario document

The key scenario is the aspired high case ambition reaching 5GW in 2030 and 34GW in 2040, which kicks off in 2027-2029 before scaling to a stable industrialised level above 2GW

Key conclusions coming from the scenarios up to 2040:

- **The key scenario for this report is the aspired high case scenario of 5GW in 2030 and 34GW in 2040.** The scenario which includes 3GW in 2030 and 20GW in 2040 is determined as a low ambition scenario, and is unaligned with government ambitions.
- These scenarios are above recent FLOW forecasting work as the aim our deployment scenarios is to establish a credible scenario in line with UK government ambitions and to assess the interventions needed to reach these ambitions.
- These scenarios are still associated with high uncertainty and will require decisive actions and industry acceleration in order to be viable.
- The scenarios indicate that deployment will **kick-off between 2027-2029**, reaching a stable industrialised **annual FLOW deployment level above 2GW from 2030 onwards** in the aspired high case.
- Up to 2030, the progress of several larger floating **ScotWind projects are assumed to play a significant role for UK deployment**. Towards 2040 the majority of the installed capacity is also assumed to be in Scottish waters due to the region's advanced industrialised position. **Celtic Sea developments are at an earlier stage of commercial maturity but show high potential** and are expected to develop later in time, unpinned by significant early-stage support.
- **This scenario excludes the deployment in North East England and Northern Ireland**. Although these regions have significant long-term potential, there is high uncertainty on deployment levels and developments are considered too early-stage to translate these into an adequate 2040 scenario and related industry interventions. **The outcomes of this report can be used for long-term 2040-2050 plans and later stage planning including North East England and Northern Ireland.**
- **The business-as-usual (BaU) scenario is not used as a driving scenario for this roadmap, but is there to determine the additionality of the economic value generated by this roadmap**. To create a realistic view on the added value of this roadmap, we calculated the difference in economic value and job creation between the ambitious scenarios and the BaU scenario. In this scenario FLOW is expected to develop regardless of this roadmap, but at a lower pace and scale, and more firmly supported by overseas port and industry capacity.

ORE Catapult FLOW Deployment scenario *(cumulative FLOW capacity in GW)*



Annual FLOW deployment scenarios used in this study *(capacity in GW)*

Annual Deployment	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Total
Low ambition scenario	0.15	0.25	0.50	2.00	2.00	2.00	1.50	1.50	1.50	1.50	1.75	1.75	1.75	1.75	20
Aspired high case scenario	0.15	0.50	1.40	2.85	3.25	3.25	2.75	2.25	2.25	2.50	2.75	3.00	3.25	3.50	34

Source: ORE Catapult, RHDHV – Deployment scenario document

Assumptions on FLOW technology, project development and value chain activities have been drafted with experts to define port and supply chain requirements

Technology assumptions

Now that we have the deployment scenarios (how much will be deployed and when), we need to create a detailed technology assumptions list (what and how will it be installed) to assess what port infrastructure is required.

This list of technology assumptions has been created in deliberation with industry experts. There is still a high level of uncertainty, project technology differences and a variety of views of market, installation and technology expectations. For the purposes of this report, the assumptions have been fixed to conduct our port assessment.

The basis of these technology assumptions evolve around technology, scale, concepts and processes. **Specifically for this port infrastructure assessment, it is essential to identify the expected process and technical requirements related to the following value chain activities:**

a) Manufacturing, assembly and logistics of substructure types.

b) Delivery, handling and sizes of components.

c) Integration and storage process in the port.

d) Installation process from the port to the offshore location.

e) Activities and timing related to O&M and decommissioning.

This has resulted in the identification of the roles, types and dimensions of ports, with the key assumptions to determine the port infrastructure requirements listed on the right.

More detail on the specific assumptions and requirements made for ports is provided in Chapter 4. A dedicated technology assumptions document has been generated for the purpose of this project, which will be developed and finalized in line with the end-deliverable.

Project specifics

- **Size**: Common market turbine range of 17 – 20MW, determining the minimal port requirements.
- **Market influencers**: For analytical purpose, we have assumed FLOW developments are not hindered by fixed bottom demand, but potential interference is mentioned if applicable.
- **Technology neutral**: All foundation concepts are considered without market preferences or standards.
- **Substructures**: FLOW projects in the UK will deploy both steel and concrete substructures and will be assessed and treated as equal for analytical purposes.
- **Lifetime**: Asset lifetime ranging from of 30 to 35 years, including decommissioning.
- **O&M**: Load out and transportation of maintenance to and from project sites will be carried out from an O&M base mainly by Service Operation Vessels (SOVs). Large component repairs will be done by tow to port repairs.
- **Decommissioning:** is seen as a reversed process of installation.

Installation process

- **Manufacturing/assembly** facilities have a production rate of 50 units annually.
- **Steel substructures** would be predominately assembled at a quayside facility with components imported from national and global fabrication facilities.
- **Concrete substructures** would be predominantly constructed in-situ at a quayside facility.
- **Launching** of substructures is undertaken utilising a semi-submersible vessel. Where tidal ranges are unsuitable, there are alternative launching provisions (like lift systems) that could eliminate the need for semi-submersible vessels.
- **Port use**: Manufacturing, marshalling, assembly, integration and installation will utilise multiple facilities and ports.
- **Infrastructure**: Large and increased landside areas and sufficient quay-side and access dimensions are required and identified per specific port type.
- **Installation weather windows:** Assumed to be approximately 5-6 months per year.
- **Integration**: Will take place in the UK with a preferred distance within 265km from site and an annual integration rate of 25 units per facility (based on the deployment rate).

Source: TF FLOW expert input, RHDHV – Technology assumptions document

Key parameters for FLOW components and substructures have translated into infrastructure requirements for manufacturing, assembly and integration port facilities

Turbine and substructure assumptions & parameters

For the purpose of this port study we have made the following additional assumptions:

a) Integration, steel assembly and concrete manufacturing will take place in the UK since activities are preferably close to the project area to reduce both risk and cost. Additionally, in the context of increased global competition, it is essential to secure supply and setup logistical capabilities in the UK to assure targeted deployment as well as generate economic added value.

b) The timing and number of ports required is based upon the deployment rate in a specific year combined with the Wind Turbine Generator (WTG) and substructure parameters.

c) Port infrastructure will need to be operational about 18 months in advance of project execution. This is to ensure they are ready to receive substructures and components, allow for testing whilst it also assures smooth operation when required.

d) The estimated spatial requirements are based upon a pro-rata of the area requirements determined for industrialised scale facilities and are intended to give an indication of the size of port facilities.

There are currently a wide range of floating substructure concepts in development, and it is unlikely that a standardised solution will become prominent during the early years of FLOW deployment. Based on the available information relating to the ScotWind leases and Celtic Sea development areas, provisionally, the deployment of semi-submersible floating substructures appear to be the favoured solution. Barge type, TLP and SPAR concepts are also under consideration at this point in time.

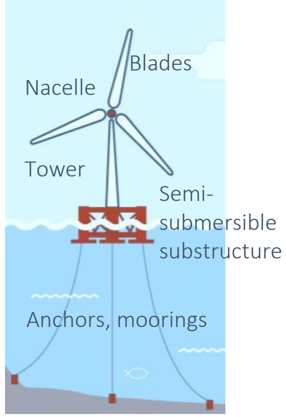
Therefore, for the purpose of determining port infrastructure requirements, the floating substructure parameters for this study will be based on a semi-submersible type foundation, as this typically represents the larger envelope of substructure types. The other types of floaters, being barges, TLPs and spar type foundations, have been considered for the estimation of the footprints, construction stage drafts, quayside water depths and channel requirements as well.

While this study acknowledges that FLOW could deploy at a faster rate, and projects and turbines could be bigger than anticipated, we have extrapolated averages based on current market conditions and expectations.

It must be noted that there are technology options and innovation initiatives that could limit draft requirements, like grounding barges, buoyancy modules, and hiring capable offshore vessels.

WTG Component Parameters

WTG SIZE	COMPONENT	No. PER WTG	LENGTH (m)	WIDTH (m)	HEIGHT (m)	WEIGHT (t)
17MW	Blade	3	130	6.5	6.5	68
	Nacelle	1	25	13.0	13.0	860
	Tower Section	4	36	10.0	10.0	300
20MW	Blade	3	147	7.0	7.0	80
	Nacelle	1	26	14.0	14.0	1020
	Tower Section	4	40	11.0	11.0	350



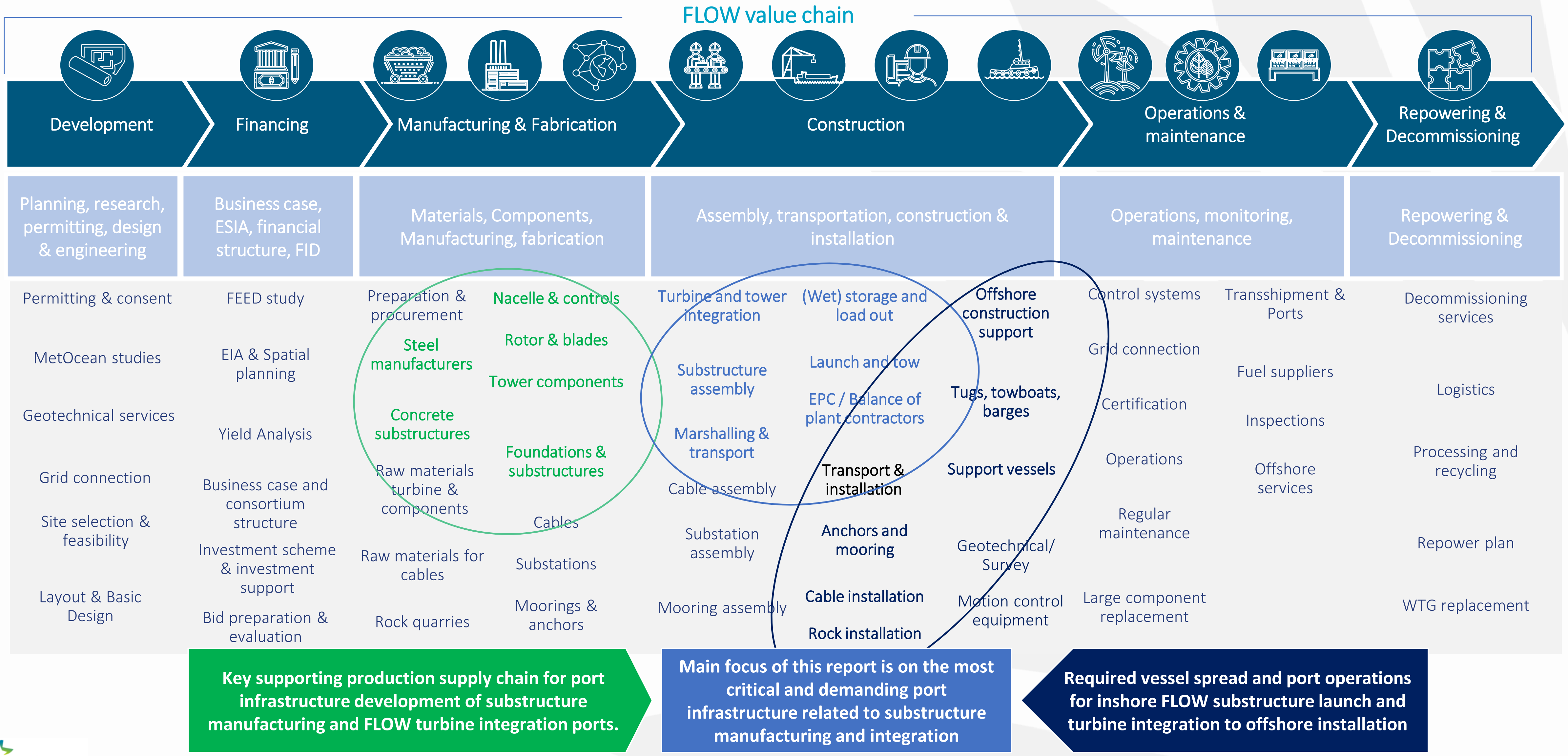
Floating Substructure Parameters

WTG SIZE	MATERIAL	LENGTH (m)	WIDTH (m)	HEIGHT (m)	WEIGHT (t)	DRAFT EXCL. WTG (m)	DRAFT INCL. WTG (m)	DRAFT OPERATIONAL (m)
17MW	Steel	90	90	27.5	3,500	11.5	13.5	22.5
	Concrete	90	90	27.5	17,500	11.5	13.5	22.5
20MW	Steel	100	100	30	4,000	13.0	15.0	25.0
	Concrete	100	100	30	20,000	13.0	15.0	25.0

- *Although steel substructures are lighter than concretes substructures, similar draft requirements have been adopted as it is assumed that these are required for stability of the floating structures.*
- *Parameters are derived from projections based on available information for smaller substructure units and are subject to change dependent on technological development and selected design solutions.*

Source: TF FLOW expert input, RHDHV – Technology assumptions document

This report focuses on the most critical and demanding activities linked to FLOW ports: manufacturing and assembly of substructures and the integration and installation of turbines



FLOW value chain

Development

Planning, research, permitting, design & engineering

- Permitting & consent
- MetOcean studies
- Geotechnical services
- Grid connection
- Site selection & feasibility
- Layout & Basic Design

Financing

Business case, ESIA, financial structure, FID

- FEED study
- EIA & Spatial planning
- Yield Analysis
- Business case and consortium structure
- Investment scheme & investment support
- Bid preparation & evaluation

Manufacturing & Fabrication

Materials, Components, Manufacturing, fabrication

- Preparation & procurement
- Steel manufacturers
- Concrete substructures
- Raw materials turbine & components
- Raw materials for cables
- Rock quarries
- Nacelle & controls
- Rotor & blades
- Tower components
- Foundations & substructures
- Cables
- Substations
- Moorings & anchors

Construction

Assembly, transportation, construction & installation

- Turbine and tower integration
- Substructure assembly
- Marshalling & transport
- Cable assembly
- Substation assembly
- Mooring assembly
- (Wet) storage and load out
- Launch and tow
- EPC / Balance of plant contractors
- Transport & installation
- Anchors and mooring
- Cable installation
- Rock installation
- Offshore construction support
- Tugs, towboats, barges
- Support vessels
- Geotechnical/ Survey
- Motion control equipment

Operations & maintenance

Operations, monitoring, maintenance

- Control systems
- Grid connection
- Certification
- Operations
- Regular maintenance
- Large component replacement
- Transshipment & Ports
- Fuel suppliers
- Inspections
- Offshore services

Repowering & Decommissioning

Repowering & Decommissioning

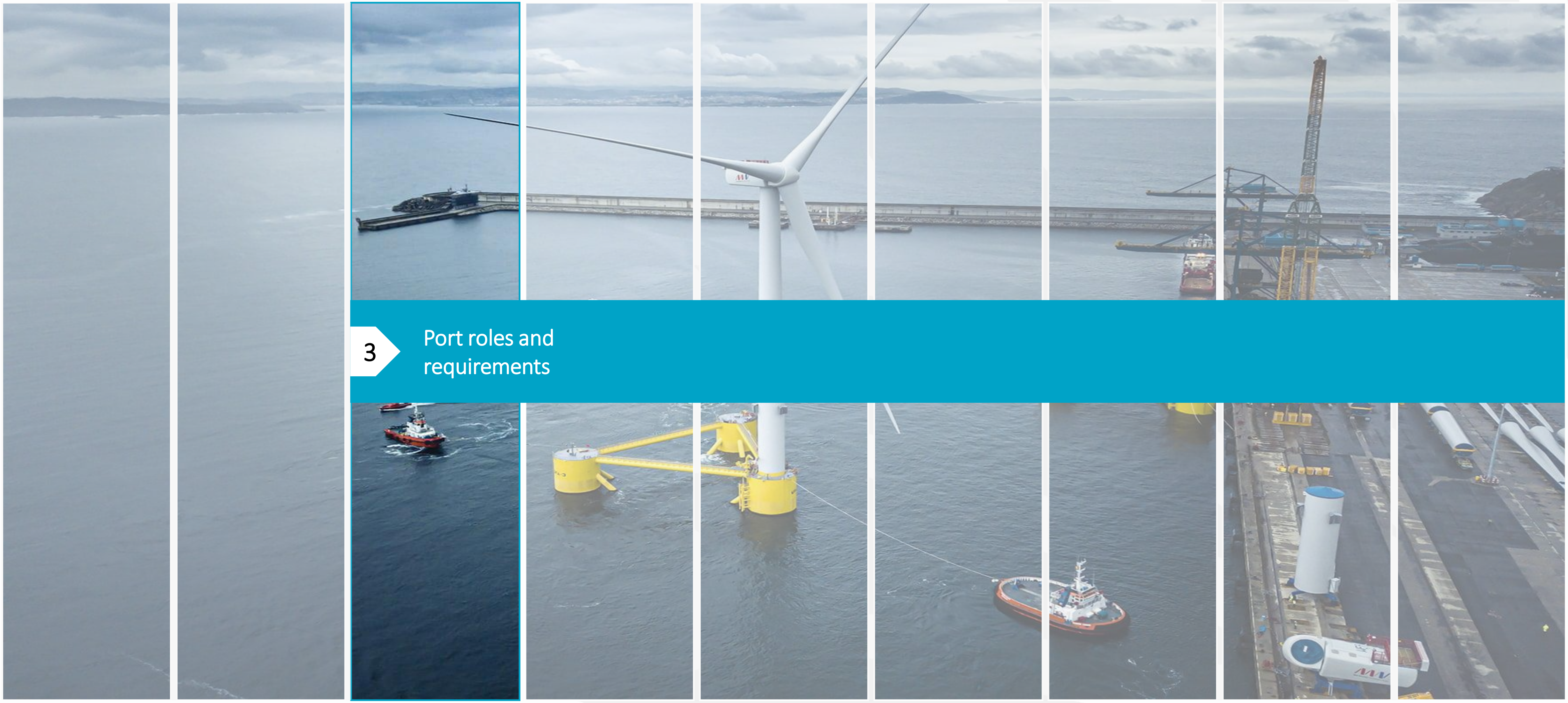
- Decommissioning services
- Logistics
- Processing and recycling
- Repower plan
- WTG replacement

Key supporting production supply chain for port infrastructure development of substructure manufacturing and FLOW turbine integration ports.

Main focus of this report is on the most critical and demanding port infrastructure related to substructure manufacturing and integration

Required vessel spread and port operations for inshore FLOW substructure launch and turbine integration to offshore installation

Source: RHDHV expert analysis

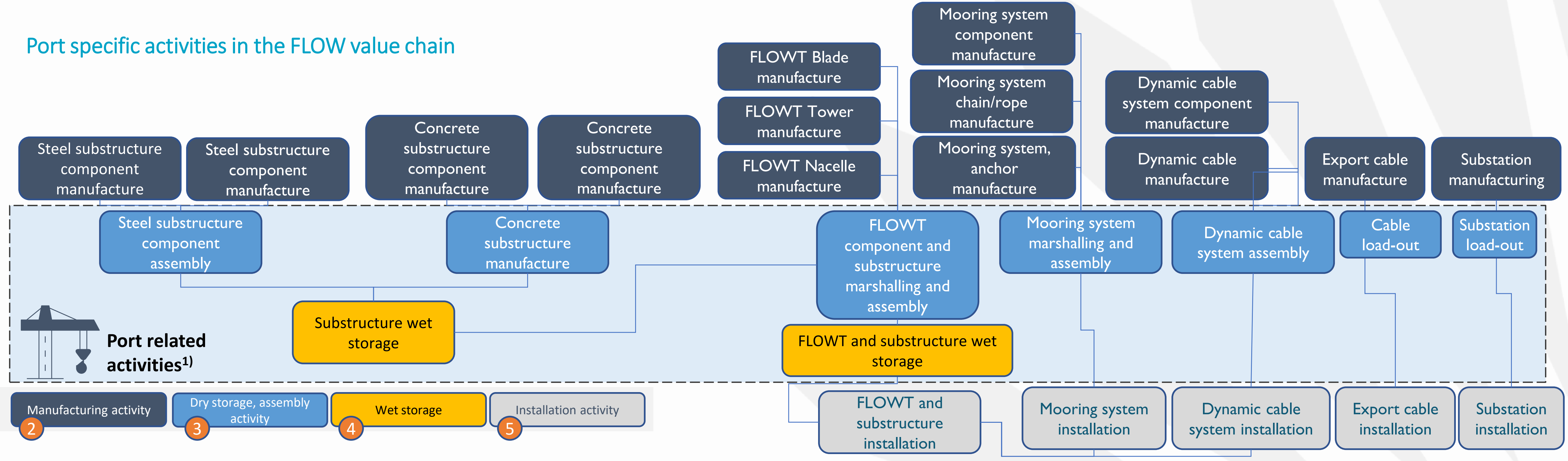


3 Port roles and requirements

Image source: GWEC

FLOW projects are manufactured, integrated, installed and operated by using a diversified value chain which drive port requirements and capacity on the back of industry scaling

Port specific activities in the FLOW value chain



FLOW projects are manufactured, installed and operated by using a diversified value chain of multiple production, port and installation facilities and assets. This value chain consists of:

① **A supply chain of base materials** used for component manufacturing, which can be delivered from UK-wide, European or even global locations (not in this visualisation).

② **A range of manufacturing activities for components**, being: substructures (steel and concrete), FLOW turbines (blade, tower, nacelle), mooring systems, anchors and cables (dark blue boxes).

③ These components are mainly being **transported by means of shipping from multiple manufacturing locations**. Multiple port facilities are needed to provide transport, marshalling, assembly and storage services, to get the right technology efficiently at the right project locations. Which in terms of industrialised scale development is preferably close by.

④ Some of the components are **delivered directly to the project site for offshore installation but the larger components are moved to a staging/integration port.** In these ports, the FLOW turbines are made ready for installation by means of assembly and dry storage of key components, (partial) integration and (potentially) wet-storage before towing out for installation. For FLOW activities, different from fixed-bottom, ports play a more prominent role and proximity is key for installation.

⑤ With the substructure and turbine being integrated, and most of the mooring systems being pre-installed, **offshore installation consists of towing out the integrated FLOW turbine, mooring the floating offshore wind structure, and the installation of dynamic cables, and the direct transport & offshore installation of export cables and the substations.**

Source: ORE Catapult

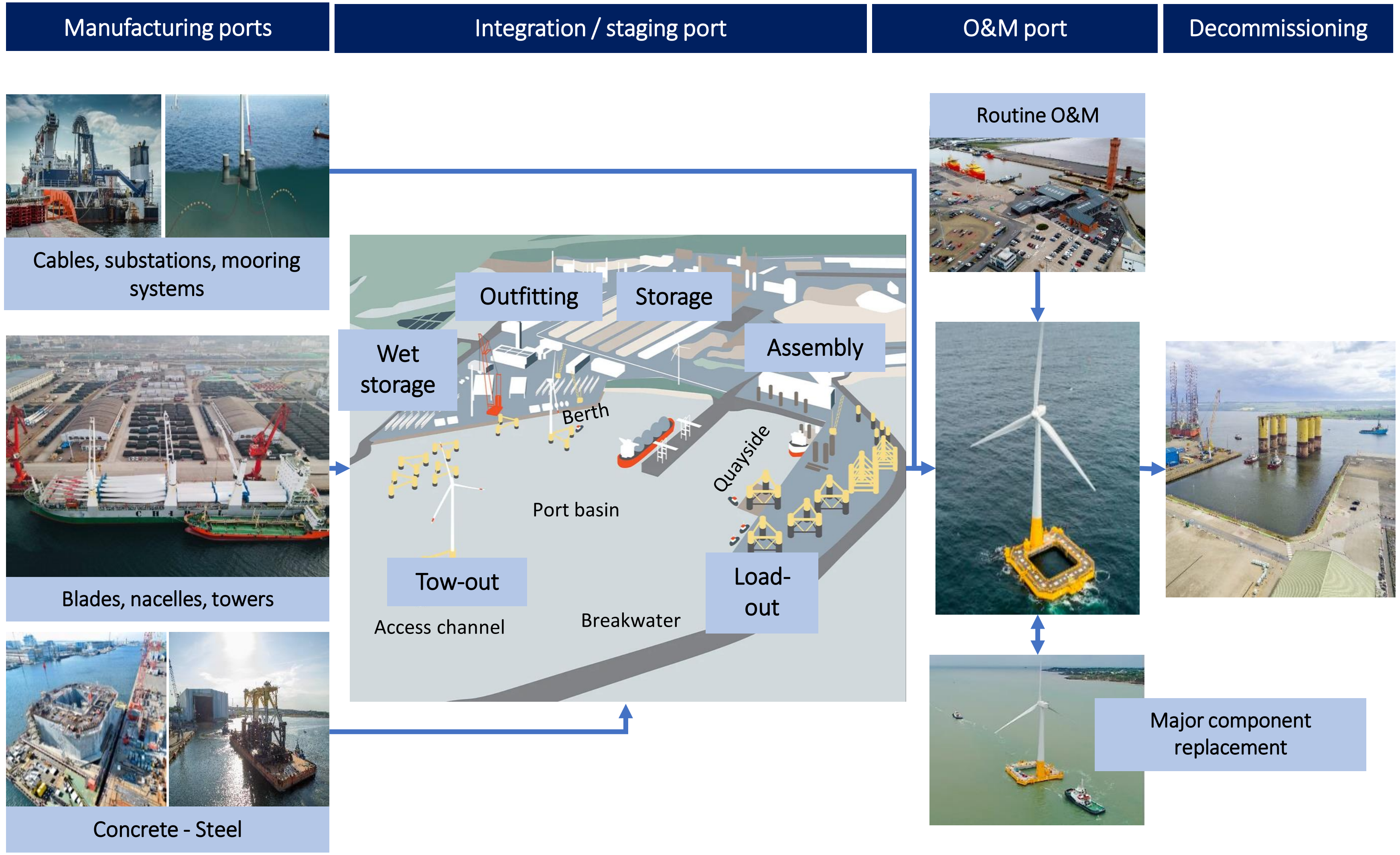
Note: 1) Export cable and substations have been excluded from this visualisation

In FLOW, ports have a more essential role compared to fixed bottom. A combination of inshore substructure assembly and turbine & substructure integration needs to take place in the port

Role of ports

Ports play a central role for all FLOW deployment stages.

- The delivery of turbine components, cables, substations, mooring systems and substructures will be carried out in existing or future manufacturing locations within the UK, north-west Europe, or even further abroad.
- The assembly and integration activities as well as the expected scale, will require ports to have significant infrastructure available in proximity of projects.
- UK ports will play a role by importing (and exporting) key components for FLOW projects and they will serve as manufacturing/assembly ports. Ideally, they are close to deep-water facilities and projects, but could also be located further away.
- As FLOW turbines are expected to be fully integrated in the port before being towed offshore for installation, FLOW requires integration ports in which all components and substructures can be stored, assembled, loaded out, outfitted and wet-stored.
- Throughout the asset lifetime of FLOW projects, ports can also support O&M and decommissioning activities. Dedicated O&M ports or larger hub ports should be able to ensure access for tow-in of structures and provide lay-down areas or hinterland connections for end-of-lifetime facilities.



Manufacturing ports

Integration / staging port

O&M port

Decommissioning

Cables, substations, mooring systems

Blades, nacelles, towers

Concrete - Steel

Outfitting

Storage

Wet storage

Assembly

Tow-out

Load-out

Routine O&M

Major component replacement

Source: Port Talbot, Cromarty Firth, MDPI, COWI

Ports are critical to reach the attainable scale, productivity and efficiency in the supply chain, and consequently for the feasibility and commercial viability of FLOW deployment

Value of and need for port infrastructure

Central role

- **Ports are an integral part of the FLOW supply chain** as they function as an interface between land based and marine activities.
- They play a role in all offshore wind project development stages.
- **Ports also have a central role in catering for operations and maintenance facilities required** to support a larger fleet of specialised offshore wind vessels, large component replacements for FLOW, upcoming decommissioning projects and hosting new manufacturing centres for floating offshore wind.
- Flow will require significant land areas, reinforced quays, enhanced deep-sea harbours and other civil works to deploy at scale.
- **Ports will also increasingly play a central energy hub role** in the production, conversion, storage, distribution, and provision of renewable energy and alternative fuels.

Enablers of scale

- **When considering the rapid expansion of fixed bottom and floating offshore wind** ports need to plan logistics and infrastructure based on the number, type and size of turbines and foundations to be installed, rather than additional gigawatts.
- **Port capacity and expansion options will determine the scale and suitability of designs and solutions for substructures and turbines.**
- Port capacities and capabilities in terms of maximum weights, dimensions, draught and quayside space could be limiting factors to the technical feasibility of larger turbines.
- Ports also need to enable scale by **assuring access for larger substructures and support vessels**.

Project proximity

- **Integration or staging ports are required to be in relative proximity to the FLOW site** to reduce the duration of installation and optimise the use of weather windows.
- With regards to **selecting an O&M base port, the distance between the port and development is a critical factor.** Typically, Crew Transfer Vessels (CTVs) are used for distances up to 50-100 km and for distances exceeding this Service Offshore Vessels (SOVs) are utilised.
- **Other proximity elements that play an important role are the presence of a supply chain and the presence of skills and workforce.**
- The importance of location, infrastructure demands and industry-relevant supply chain presence **need to be optimised and tailored to the port and regional situation.**

Efficiency

- *WindEurope Ports Platform, based on BVG analysis released in September 2018,* concludes that **investments in new port infrastructure of €0,5-1bn could help the offshore wind sector reduce costs by 5,3%. This investment would enable ports to offer efficiencies and to consolidate operations, maintenance and services in hubs.**
- Ports can improve efficiency and find alternative solutions to reduce time and logistics costs. For example, FLOW onshore preassembly of turbines is preferred from a technical and risk perspective, but also reduces installation logistics costs significantly for developers.
- **Ports can also support low-carbon activities** by providing charging and alternative fuel bunkering facilities for installation and O&M vessels.

Sources: RHDHV, Wind Europe, Online sources

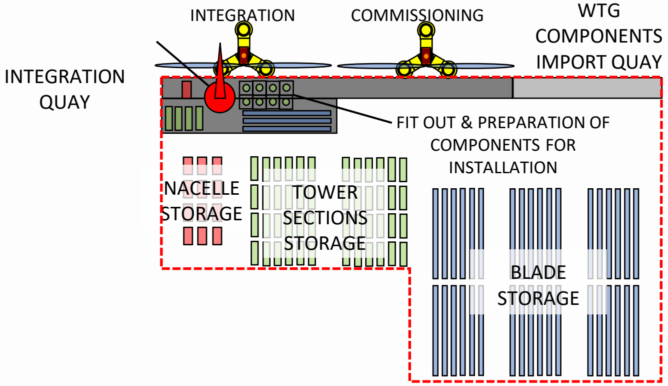
Three port types are considered in this report as critical to deliver FLOW projects. The key requirements give an indication of the long-term dimensions these ports have to evolve into

Critical port types

The key port requirements give an indication of the long-term dimensions to service large scale FLOW deployment. These dimensions can be the result of ports evolving over time to assure they grow with market scale and are future-proofed. **Existing ports with known parameters and sufficient supporting capacity (tug, cranage, launch facilities) could work with lower channel widths and reduced depth requirements, as circumstances and actual requirements are very site specific.**

Integration port

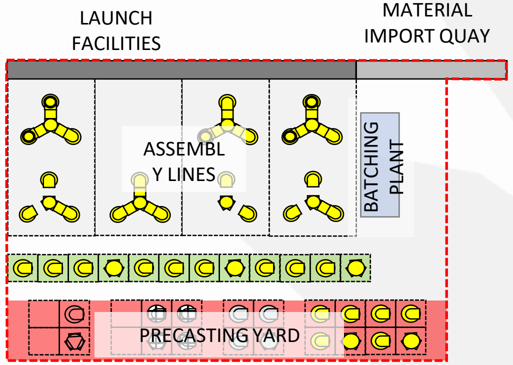
An Integration Port is a facility in the vicinity of the wind farm used to install the wind turbine on the substructure prior to deployment offshore.



KEY REQUIREMENT[1]	17MW	20MW
Distance from Wind Farm (km)	265	265
Entrance Width (m)	120	130
Air Draft (m)	Unrestricted	Unrestricted
Access Channel Width (m) [1]	230	260
Access Channel Water Depth (m below MLWS)	15.0	16.5
Landside Area (ha)	20	25
Integration Quay Length (m)	400	440
Integration Berth Water Depth (m below CD)	15.0	16.5

Concrete manufacturing port

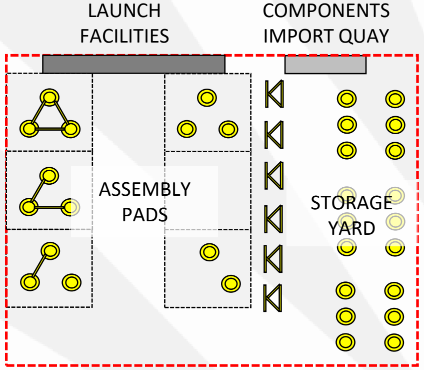
A concrete manufacturing port, which can be further away from project sites, is a facility where concrete substructures are manufactured and assembled.



KEY REQUIREMENT[1]	17MW	20MW
Entrance Width (m)	120	130
Air Draft (m)	50	50
Access Channel Width (m) [1]	230	260
Access Channel Water Depth (m below MLWS)	13.0	14.5
Landside Area (ha)	30	40
Launch Quay Length (m) [2]	520	560
Launch Berth Water Depth (m below CD)	8.5	8.5
Manufacturing Duration for Substructure (wks)	13	13
Number of Assembly Lines (No.) [3]	4	4

Steel assembly port

A steel substructure assembly port, which can be further away from project sites, is an intermediate facility used to construct steel substructures before being transported to an integration site.



KEY REQUIREMENT[1]	17MW	20MW
Entrance Width (m)	120	130
Air Draft (m)	50	50
Access Channel Width (m) [1]	230	260
Access Channel Water Depth (m below MLWS)	13.0	14.5
Landside Area (ha)	30	40
Launch Quay Length (m) [2]	275	275
Launch Berth Water Depth (m below CD)	8.5	8.5
Assembly Duration for Substructure (wks)	6	6
Number of Assembly Pads Required (No.) [3]	6	6

Note:
1) Access channel width accounts for the width of a substructure plus an allowance for clearances in accordance with the recommendations of PIANC 121
2) Launch quay length is dependent on landside layout and launch methodology and could be similar for either concrete or steel substructures
3) Concrete substructures are manufactured on an assembly line with maximum duration at a bay of 4 weeks, steel assembly substructures remains on a single assembly pad until completed

Basic port infrastructure for concrete and steel could be developed in a similar way so usage could be converted with changes to the landside support infrastructure

Comparing concrete and steel requirements

In this study we have considered both concrete and steel substructure types, as the direction of the preferred technology is unclear, and under the assumption that both technologies and supply chains will need to be developed to deal with market demand.

In general, just like in offshore O&G and fixed bottom offshore wind, steel might be expected as dominant. However, concrete could well emerge with projects being favourable for concrete concepts. Some promising concepts are being developed and the presence of an existing local concrete manufacturing supply chain could reduce dependence on the global steel manufacturing market.

When assessing steel assembly and concrete manufacturing there are some differences and commonalties in the specific requirements.

Generally, port infrastructure requirements are to some extent similar for the two facility types. Therefore, it should be possible to convert a port facility from one type to the other depending on which material type becomes dominant in the market. Developing common base infrastructure also reduces the risk of to heavily betting on one specific technology.

The requirements for concrete manufacturing facilities seem more demanding as ports will have to deal with heavier substructures and components, which require higher bearing capacities in the quay and quayside areas. This potentially makes it more feasible to convert concrete facilities into steel assembly ports, if steel turns out to be dominant substructure material.

A detailed study of the manufacturing requirements for both concrete and steel substructures needs to be undertaken to validate the initial assumptions and determine common infrastructure requirements for future port designs.

	Concrete manufacturing port	Steel assembly port
Port infrastructure	▪ Similar entrance, landside requirements ▪ **Higher bearing capacity requirements due to heavier substructures (circa 20,000t)** ▪ **More onerous landside transportation requirements** (i.e. skid transfer rails) due to higher loads	▪ Similar entrance, landside requirements ▪ Lower bearing capacity requirements due to lighter substructures (circa 4,000t) ▪ Components and substructures can be transported utilising SPMTs ▪ Noted that quay facilities are dependent on geometry of site and supply chain logistic and therefore are not considered a significant differentiator
Launch & depth	▪ Similar access channel and launch berth water depth ▪ **Careful consideration of how substructures are moved to quayside** is required to prevent bottle-necking of production lines	▪ Similar access channel and launch berth water depth. ▪ Noted that steel substructures are lighter than concrete structures and therefore **lesser water depths for steel substructures may be acceptable** provided that they have adequate stability at these draughts.
Supply chain needs	▪ Lower skills threshold with **more opportunity for workforce to move from existing buildings and civils construction industry** ▪ **Benefits from local supply** of raw materials for concrete production ▪ **Production is likely to take longer** but can utilise production lines for efficiency	▪ **Higher skills threshold for welding and steel assembly operations** ▪ Components imported from fabrication facilities either nationally or internationally

Crane capacity could be a potential bottleneck. A flexible approach on innovative lifting solutions, asset financing and utilisation, and use of standardised components is key

Cranage

- With water depths at sea currently ruling out offshore assembly solutions, the most efficient way to integrate turbines onto floating foundations is to **assemble and integrate the substructure onshore and in port waters directly alongside the quay, by using a combination of large cranes**. Furthermore, fabricating floating foundations at port will also pose a significant challenge for facilities in terms of land area, ground reinforcement and crane capacity.
- For substructures, weights are expected to be 3,500 – 4,000t for steel and 17,500 – 20,000t for concrete. To support manufacturing/assembly a combination of gantry, tower, mobile and crawler cranes will be utilised. Self-Propelled Modular Transporters (SPMTs) and transfer rail systems are needed to move foundations to their launching facilities.
- The large dimension of the expected turbine sizes will pose a huge challenge in terms of lifting capacity, hook heights and air draft. 20MW turbine nacelle weights are expected to reach 1,000t with hub heights in excess of 150m. **This means that the largest crawler cranes currently in the market are not sufficient, and cranes that can accommodate these requirements are extremely limited in numbers. The hub height at which the nacelle has to be installed is a limiting factor for available onshore cranes and for existing floating crane vessels.**
- Turbine assembly can also by carried out using jack-up vessels or semi-sub cranes inshore. Whilst this could provide a viable solution for the heavy lifting, the expected logistics and lifting operations will not be ideal due to space constraints of having both a floating vessel and the FLOW unit berthed at the quay edge. Crane vessels will also be constrained by growing turbine dimensions and higher rates for such vessels as they will be competing with other fixed bottom offshore wind installation projects. **Leasing rates for large crane vessels range from £100k – 600K/day compared to the likely lease rates for ringer cranes of ~£60K/day. Potentially offshore installation vessel schedules can be filled by inshore lifting activities at lower cost to limit their idle time, but this will not provide a structural solution.**
- The (port) crane market is serviced by large global players, like Konecranes, Liebherr, Kenzfigee, Cargotec, ZPMC and XCMG. For large ringer cranes, there are a limited number of manufacturers including Sarens, Mammoet and Huisman. **The cranes with sufficient lifting and reach capability are limited in global availability**. Given the fast-growing scale of turbines requiring large assets and the large capital expenditure investment (>£70mn) to purchase ringer cranes, it seems unlikely to be appealing for ports. Consequently, **lease concepts provide greater flexibility and limit upfront investment and may be more attractive.**
- As size, availability, utilisation and investments in cranes could be a major bottleneck for manufacturing, assembly and integration securing crane capacity and flexible solutions is essential. For both fabrication and manufacturing, securing cost-attractive crane capacity at the right location at the right time is key.
- **For fabrication the right modularised construction approach will be crucial to a project's success**. Designing modules so that they can be built, transported and shipped in the most efficient way shortens overall schedules and lowers whole-project costs.
- **For ports, flexibility in crane capacity is key** with regards to cost (leasing rather than invest), flexible and temporary solutions, optimised crane utilisation (in and between ports), ability to scale capacity over time.

Technical requirements and options

Crane requirements:

- **Multiple self-Propelled Modular Transporters (SPMTs)** to move imported or manufactured components (2 – 4 SPMTs)
- **A concrete manufacturing or steel assembly port** will need a combination of gantry cranes, tower cranes and crawler cranes to transport, lift and assemble the components in the port
- **For integration in the port** a combination of a crawler/mobile cranes and large capacity ringer crane is needed
- **Inshore installation by crane vessels** could be an option to increase flexibility
- **Cherry pickers** to provide access for personnel for support activities (>30 meters)


SPMT


Tower crane


Ringer crane


Crawler crane


Semi-sub crane


Jack-Up Vessel

Development of crane capacity should focus on:

- **Flexibility**: Optimise crane use in multiple facilities by crane, port and vessel players.
- **Scaling**: Plans, concepts and business models to scale sizes in line with market sizes.
- **Alternatives**: Use of jack-up vessels or alternative solutions to limit crane dependence.
- **Commoditise**: Development of a build strategy to handle smaller components in a standardised way to optimise process, asset utilisation and limit over dimensioning.
- **Innovation**: For example, self-installing crane concepts, innovative lifting combinations to reduce large capacity needs or alternative solutions to load out.

Sources: Mammoet, Van Oord, Huisman, Liebherr, ALE

Wet storage and launching methods could be critical elements to provide adequate buffer and draft requirements. Detailed study on best approach, strategy and locations is required

Wet storage

Wet storage might not be required in all scenarios and when just-in-time delivery is viable. However, it could be a critical element of the floating offshore wind production supply chain when a buffer storage of units is required to de-risk the process in the following way:

- **Short-term wet storage of substructures at manufacturing/assembly facilities**
  Following launching of the completed floating substructure units, storage may be required until suitable weather, tidal or navigational channel access is available.
- **Long-term wet storage between manufacturing/assembly facilities and integration facilities**
  Required to compensate for differences between substructure production (all year round) and integration (deployment assumed over 6 months annually).
- **Short term wet storage of substructures at integration facilities**
  Buffer storage of substructures near to the integration facility may be required to offset the risk of weather-related delays with regard to delivery of floating substructures.
- **Short-term wet storage of completed units at integration facilities**
  Buffer storage of a limited amount of completed units may be required until suitable weather windows are available for safe deployment to the offshore site.

For safe wet storage of substructures, significant areas and water depths are required. Integrated units will require even more space for wet storage in order to take account safe spacing between rotors.

These requirements will be dependent on a number of factors including environmental conditions, the degree of sheltering at the site, substructure response (roll, pitch, heave), mooring systems and site geometry. Appropriate mooring systems, which must be quick to connect/disconnect, are required to secure assets even in the short-term and consideration should be given to establishing long-term mooring sites. It is currently unclear how the industry will approach wet storage with possible options including a) Localised wet storage at or near to manufacturing/assembly and/or integration facilities, or b) Centralised wet storage locations for multiple projects.

It is recommended that a detailed study into wet storage strategies and requirements is undertaken along with identification of suitable sites to serve the deployment scenarios for FLOW and associated environmental consenting processes. Visual impact of storing (partial) floating turbines close to shore on a recurring basis is likely to be a significant issue for local stakeholders.

Wet storage activities

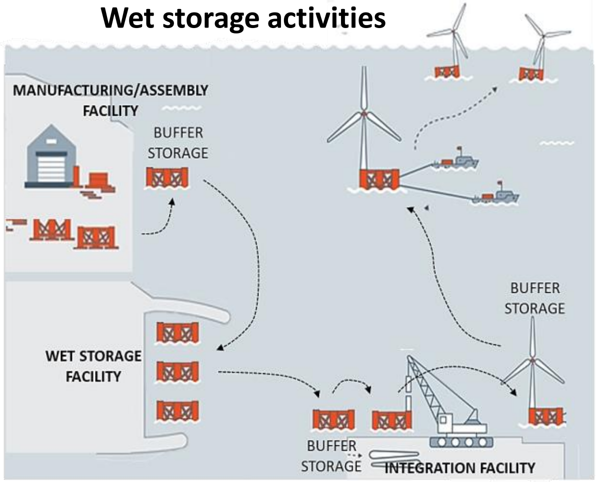


Image source: CIP

Launching Facilities

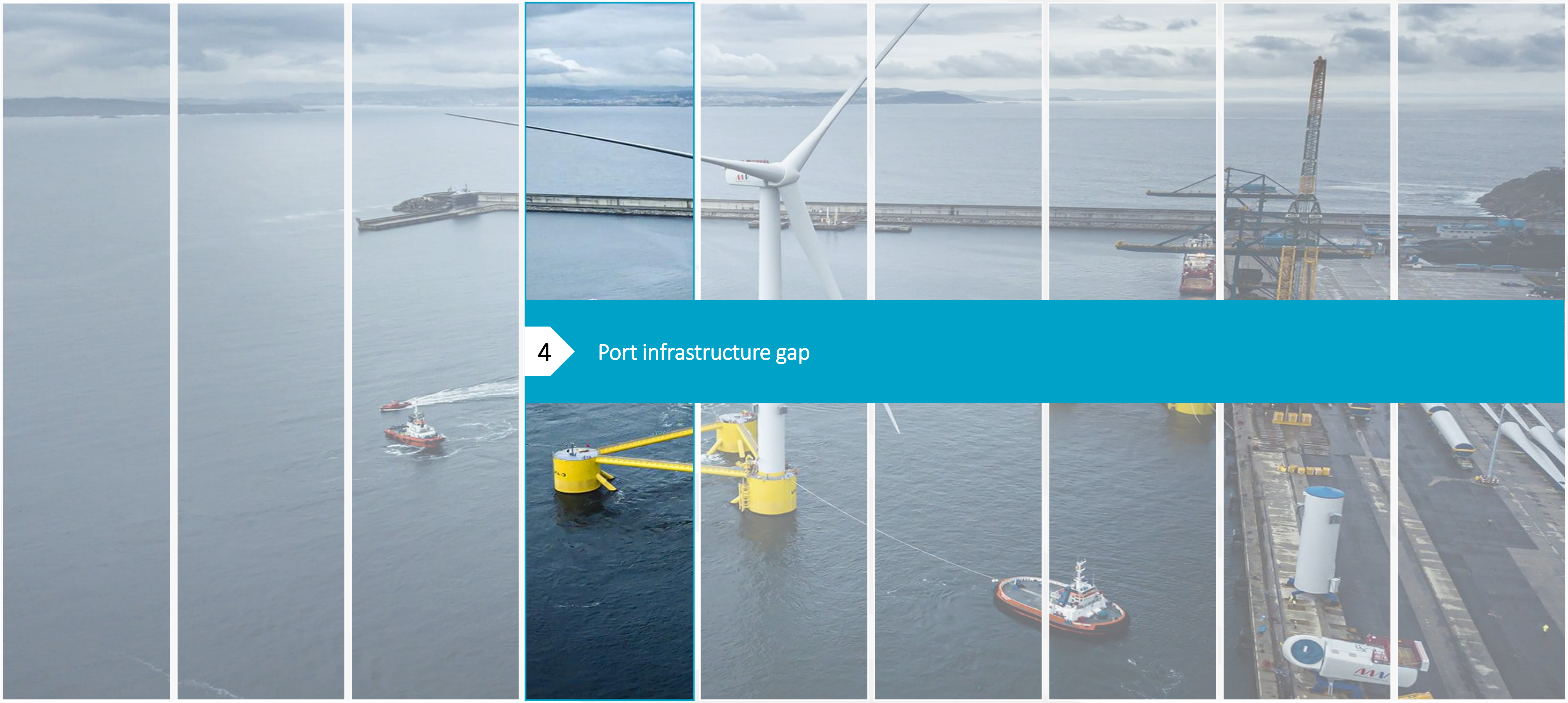
Launching facilities


Hydro-lift
Floating load-out barge
Conventional slipway

It is anticipated that substructures will be constructed on land and most likely at ground level rather than within a dry dock, so a means to launch units from quaysides into the sea will be an important consideration in facility planning and design. Concrete substructures could potentially be manufactured utilising floating slip-formed construction, but it is likely that a shore to sea launch system will still be required.

Potential options for launching system include conventional slipways or launch ways, slipways with marine railways/launching cradles, hydro-lifts, floating load-out barges, jack-up barges, bespoke floating docks, ship lifts and potentially heavy lift cranes for much lighter units.

The nature and choice of launch will be dependent on the lifting capacity needed and the physical size of units. It is anticipated that the majority of facilities would use some form of load-out barge. Barges need to be ballasted to achieve a level and stable structure during transfer with particular control being needed as the weight transfers to the barge from the quay edge. Barges would then be moved to an area of deeper water where they are ballasted and sunk, and the floating units are then launched. Where tidal ranges are higher, which can occur in some UK ports, slipways or fixed launches may be more suitable. The choice of launching method will also be influenced by the availability of land, environmental conditions, foundation build strategies and the size and weight of substructure units.



4 Port infrastructure gap

Image source: GWEC

The assessment of the port infrastructure gap is based on the needed capacity and requirements of integration and manufacturing ports on an industrialised scale

Port assessment

A gap analysis has been carried out to consider current UK port capacity and capabilities to meet the proposed FLOW deployment rates on an industrialised scale. To make this assessment, we have established some principal requirements for the different types of port which include land areas, berth lengths, access channel sizes and proximities to the project sites.

Based on these port requirements the current UK port infrastructure has been assessed to **identify capable ports that could service FLOW developments by hosting integration, manufacturing and assembly facilities**. Ports will also play a significant role in the supply chain for the import, handling and deployment of FLOW mooring systems and array cables. Whilst the scale of this opportunity will be considerable, it is expected that existing UK Port facilities can be adapted more easily to meet these requirements.

In this assessment, we have taken into account the current infrastructure and dimensions of the ports but also the potential capability of the ports that could be realised through development and investment in dedicated infrastructure. It must be noted that this assessment is based on available port information for a **non-exhaustive list of ports**. As we are not aware of all future port development plans and options, the assessment at this stage has limitations in identifying suitable ports. **Our aim is not to exclude ports or make a selection but to assess the overall status of the current UK port infrastructure and develop a set of port roles and requirements against which port plans can be tested and selected.**

In theory all manufacturing, assembly, integration and O&M activities could be undertaken from a single port facility, which would be a benefit for supply chain logistics. However, based on the expected port area requirements for industrialised scale deployment of FLOW and the current availability of port infrastructure, this is not expected to be feasible in the short term.

Instead, it is expected that ports will specialise in offering either specific services or a combination of services to support the deployment of FLOW. Taking into account supply chain logistics and transportation costs there are likely to be advantages in locating key facilities in strategic locations to offer a multi-port solution.

For the purposes of the port infrastructure gap analysis the following key activities have been considered:

- Integration of WTGs onto floating substructures
- Assembly of steel floating substructures from modular components
- Manufacturing and assembly of concrete floating substructures

In order to undertake the gap analysis of port infrastructure the following methodology has been applied:

- Determination of port infrastructure requirements for industrialised scale deployment.
- Estimation of the number of ports required to serve the regional deployment scenarios up to 2040.
- Review of current port infrastructure in the UK and screening against the identified key port requirements
- Identification of national and regional port locations that have the potential to support the deployment of FLOW up to 2040

A review of port facilities around the UK has been undertaken while current and planned key infrastructure provisions have been screened against port infrastructure requirements

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UK port assessment

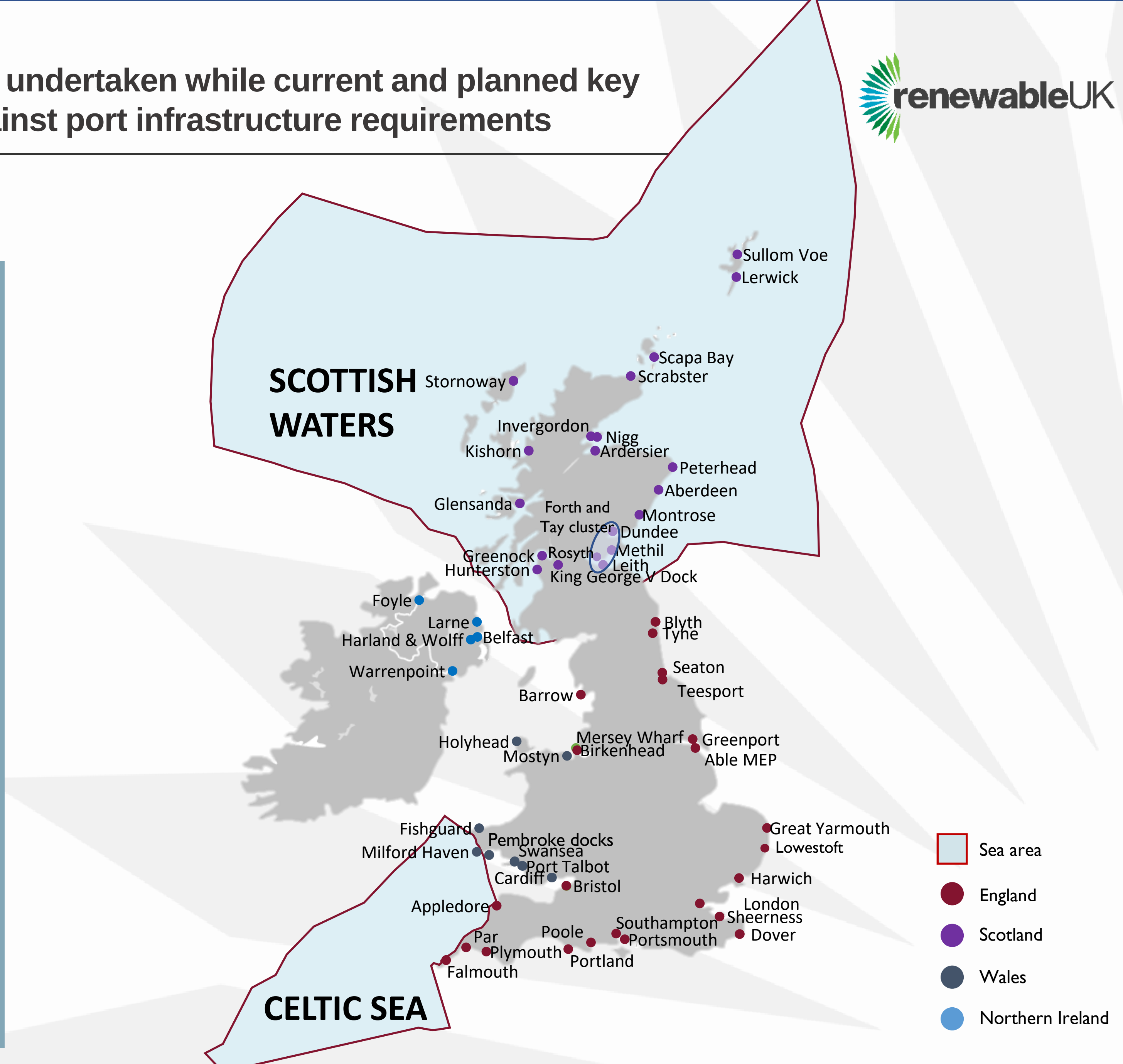
A review of port facilities around the UK has been undertaken and key infrastructure provisions, both current and planned, have been identified based on publicly available information.

It is noted that in some areas available information is limited with regard to planned developments and provisions that could be dedicated to supporting FLOW deployment.

This data has then been screened against the port infrastructure requirements determined in the previous section of the report to identify any facilities that would be suitable to host industrialised scale integration, assembly or manufacturing activities.

A further review has then been undertaken to identify suitable port locations with a high degree of potential to support these activities subject to development.

This map and the next two pages give an overview of the larger ports in the region and the wider UK that have been identified and assessed as having ambitions to develop a role or as potentially able to play a role in the integration or manufacturing and assembly of FLOW. It does not reflect a selection of ports which are deemed as most viable. Selection criteria should be based on the ability of ports to develop plans in line with the identified requirements [as part of FLOWMIS applications].



Note: This is a non-exhaustive selection of ports with potential to support FLOW in terms of manufacturing, assembly and integration based on available information

4 Port infrastructure gap

A large number of port facilities are serving a diverse range of activities, and ports have been on the forefront of UK offshore wind development

Scotland has a relatively large number of port and harbour facilities serving a diverse range of activities including, cargo, oil & gas (O&G), renewables, fishing, ferries, shipbuilding and cruise.

The O&G industry has formed a significant part of the Scottish economy and consequently a number of ports along the east coast have developed to support this industry.

The Shetland and Orkney Islands have deep water facilities for exporting O&G, whilst facilities in the Cromarty Firth region, initially developed for the construction of oil rigs, now support servicing and storage.

Also, ports in the North-East region such as Aberdeen and Peterhead are major hubs for supply and logistics. On the west coast, facilities at Kishorn and Hunterston were developed to build large oil platforms with Kishorn still being used to date. Related to this, the decommissioning of North Sea O&G infrastructure is expected to be a significant market over the coming years.

Scotland remains at the forefront of the developing offshore wind industry in Europe, and is home to the world's largest floating offshore wind leasing round, ScotWind. Consequently, ports and harbours have developed and will further develop to support the construction and O&M activities.

Similarly to O&G, most of the fixed-bottom wind farms have been developed in the North Sea with large ports in the Cromarty Firth region providing staging and marshalling services.

The rise in offshore wind deployment has seen ports undertake infrastructure projects to service industry requirements, and further FLOW developments are planned at a number of ports.

Nigg Energy Park

- Focus on renewables, O&G and decommissioning
- 12m water depth, 32ha land area, combined 720m of quay
- Potential for integration, manufacturing, assembly
- Planned tower manufacturing facility

Port of Cromarty Firth

- Focus on renewables, O&G, cruise, decommissioning
- 12m water depth, 18ha land area, combined 800m of quay
- Potential for integration, manufacturing, assembly
- Planned reclamation to add 4ha

Ardersier

- In development
- Initial 6.5m water depth, 57ha land area, combined 1000m of quay
- Suitable for integration, manufacturing, assembly
- Planned concrete barge manufacturing and integration facilities

Aberdeen

- In development
- 9m water depth, 13ha land area, combined 1400m of quay
- Integration, manufacturing, assembly, possible airport limitations

Scapa Deep Water Facility

- Currently in development
- 15m water depth, 18ha land area, combined 685m of quay
- Potential for integration, manufacturing, assembly

Stornoway

- Currently in development
- 10m water depth, 29ha land area, combined 500m of quay
- Potential for integration, manufacturing, assembly

Kishorn

- Current focus on aggregates, renewables, O&G, aquaculture
- 8m water depth, 45ha land area, 160m of quay
- Potential for integration, manufacturing, assembly
- Masterplan for FLOW developments in place

Hunterston

- Operational with further development ongoing
- 36m Water depth, 130ha land area, 800m of Quay
- Potential for integration, manufacturing, assembly
- Masterplan in place for FLOW

Dundee

- Purpose built marshalling facility
- 9m water depth, 17ha land area, combined 485m of quay
- Potential for integration, manufacturing, assembly

Leith

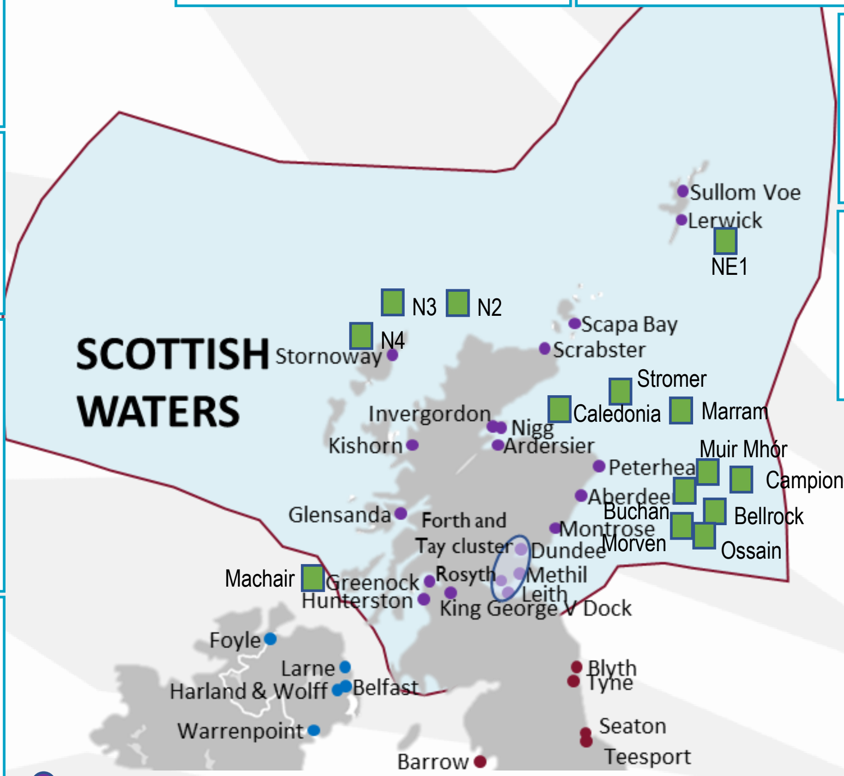
- In development
- 9m water depth, 70ha land area, 120m of quay + dolphins
- Potential for integration, manufacturing, assembly

Methil

- Operational with further development ongoing
- 10m water depth, 55ha land area, 360m of quay
- Suitable for integration, manufacturing, assembly

Teesport

- In development
- 15m water depth, 50ha land area, 400m of quay
- Suitable for manufacturing, assembly
- Phase 2 provide additional 600m of quay and 150ha of land area



● Larger Scottish ports in the region (non-exhaustive)

🟩 Scotwind FLOW projects with apparent grid connection agreements in the National Grid TEC register

Note: This is a non-exhaustive selection of ports with potential to support FLOW in terms of manufacturing, assembly and integration based on available information

A limited number of UK ports have deep water access required to support industrialised scale FLOW activities, but ports are actively seeking developments to service the UK flow market

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The Celtic Sea region is generally bordered by Wales and South-West England.

There are a diverse range of port and harbour facilities in the region serving activities including shipbuilding/ship repair, cargo, liquid bulk, dry bulk, aggregates, steel, tourism & leisure, ferries, and renewables.

There has not been any significant development of fixed-bottom wind in the region and subsequently there has been no economic incentive for ports to develop facilities to support this industry until recently.

A small number of ports, particularly in the north Wales region have supported activities associated with the deployment of fixed-bottom wind farms in the Irish Sea.

For the Celtic Sea projects, a broader selection of potential manufacturing and assembly sites in England, Wales have been taken into account.

Due to a lower level of industrial development there are a limited number of ports in the region that have deep water access required to support industrialised scale FLOW activities. Additionally, there are a number of port facilities that could accommodate routine O&M facilities to support FLOW deployment.

Ports in the region are aware of the opportunity presented by the development of offshore floating wind, and a number of ports are actively seeking to develop facilities in order to support this.

Belfast

- Existing facility with expansion are identified
- Potential 10m water depth, 40ha land area, combined 820m of quay
- Potential for manufacturing/assembly and partial integration

Pembroke Docks

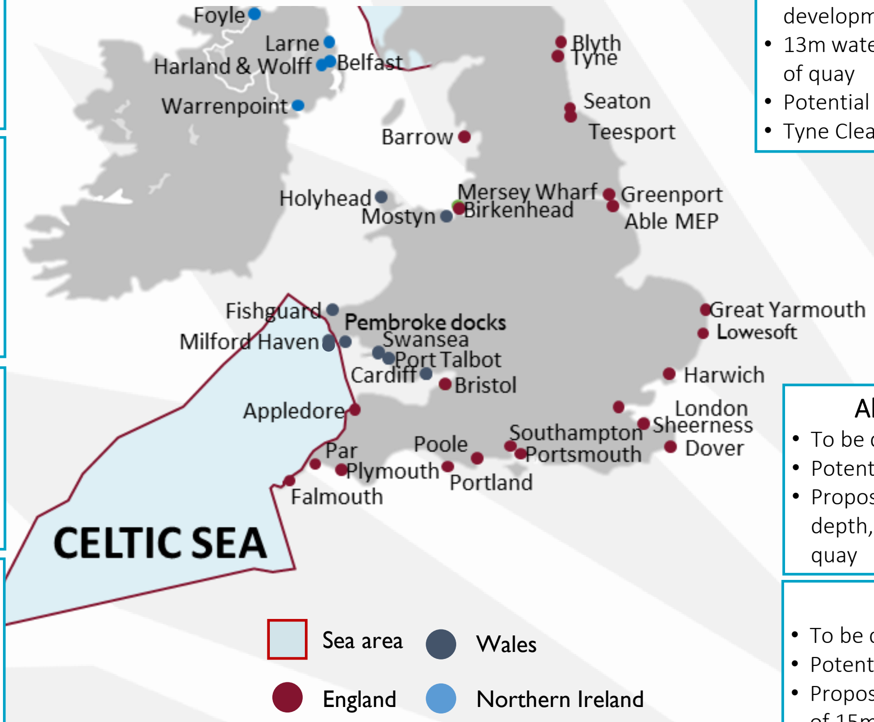
- Largest UK energy port, with a focus on ferry, O&G, aggregates
- 6m water depth, 8ha land area, 200m of quay
- Potential for integration, manufacturing, assembly
- Potential for development of 25+ ha land area and 600m of quay

Port Talbot

- Planned development of tidal harbour for FLOW
- 12m water depth, 60+ ha land area, combined 1200m of quay
- Potential for integration, manufacturing, assembly

Port of Holyhead

- Current focus on passengers, bulk, fishery
- 7m water depth, 220m of quay
- Experience with fixed bottom
- Investment plan for wind turbine stating
- Potential for manufacturing, assembly



Tyne

- Operational with expansions in development
- 13m water depth, 30ha land area, 240m of quay
- Potential for manufacturing, assembly
- Tyne Clean Energy Park in development

Able Seaton

- Renewables, O&G, Decommissioning
- 11m water depth, 50ha land area, 830m of quay
- Potential for manufacturing, assembly

Able Marine Energy Park

- To be developed
- Potential for manufacturing, assembly
- Proposed development of 11m water depth, 170ha land area and 1350m of quay

Harwich

- To be developed
- Potential for manufacturing, assembly
- Proposed Bathside Bay Development of 15m water depth, 120ha land area and 450m of quay

Bristol

- Bulk, RoRo, Container, Project Cargo, Break Bulk
- Currently 14.5m water depth, facilities behind lock gates, 40 ha of land available
- Potential for integration, manufacturing, assembly
- Consented plans for repurposing port area outside lock gate area, potential for FLOW deep water facility with 40ha of land

Falmouth

- Ship repair, fabrication
- 8.5m water depth, 5.6ha land area, 235m of quay
- Potential for integration
- Planned development for 9ha land area and 490m of quay

Portland

- Cruise, Leisure, Bulk
- 12m water depth, 4ha land area, combined 2000m of quay
- Potential for manufacturing, assembly
- Development required to create port infrastructure

Note: This is a non-exhaustive selection of ports with potential to support FLOW in terms of manufacturing, assembly and integration based on available information

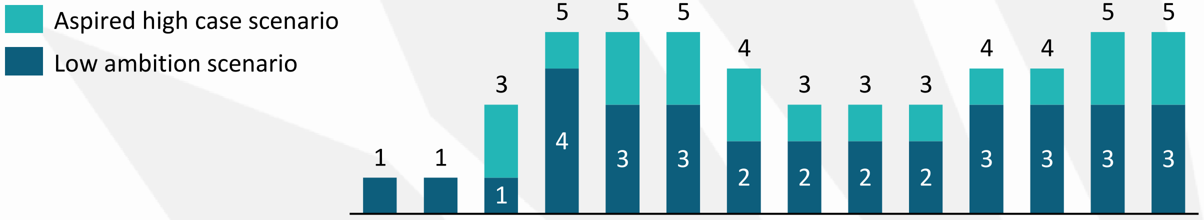
There are no port facilities in the UK which fulfil integration port requirements, an industry approach towards port development is needed

Port capacity need: Integration port

- Prior to 2030 there are a relatively small number of floating wind turbines being deployed annually. These are considered to comprise demonstrator and early commercial projects which will trial a number of different substructure concepts, for which quaysides with sufficient bearing capacity and space for integration needs to be ensured. Port requirements will be heavily influenced by individual project requirements and developers may deem it beneficial to consolidate manufacturing/ assembly and integration facilities at a single port for each project. Also, alternative and innovative solutions to reduce draft requirements can be tested and deployed to support initial deployment and prepare for industrial scale.
- **However, taking into account the lead-time on assembly and buffers required for an efficient integration and deployment programme, ports need to be ready to start accepting components and commence fabrication in 2028-2029 to ensure deployment rates are achieved.** From 2030 there is a sharp rise in deployment numbers to levels where several industrialised scale integration facilities (25 units p.a.) could be utilised, implying that port upgrades need to be ready early 2028.
- **In Scotland** there is a peak in deployment numbers during the early 2030's followed by a drop due to the INTOG programme coming to an end. From the mid 2030's up to 2040, there is a steady increase in deployment numbers. **Four ports on the east coast of Scotland and four ports on the west coast of Scotland have been identified with potential to be developed into industrialised scale integration facilities to support FLOW deployment**. The key limitations of the existing port infrastructure are based around the significantly larger width and drafts of the floating substructures as well as the increasing access channel and berth requirements. Additionally, at most existing port facilities there is limited available land area.
- **In the Celtic Sea,** the deployment numbers for the 3GW low ambition scenario remain consistent up to 2040 and for the 5GW scenario, the deployment numbers rise steadily up to 2040. **3 ports have been identified which, with varying degrees of investment, could be developed to provide industrialised scale integration facilities to support FLOW deployment in the Celtic Sea**. Generally, these ports are aware of the opportunities around FLOW and are in the process of planning facilities to support floating offshore wind deployment. The key limitations of the existing port infrastructure are that sufficient quayside facilities and landside areas have yet to be developed.

Scotland Regional Integration Port Facility Requirements up to 2040

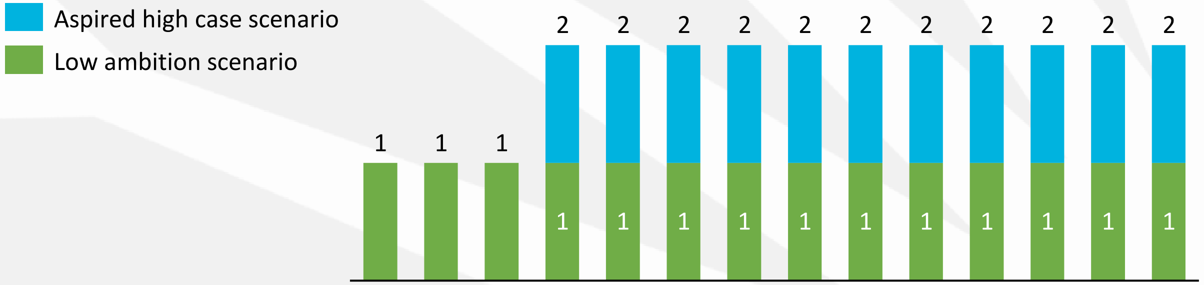
(number of integration ports required per annum based on annual deployment rate)



SCENARIO	SCOTLAND (Incl. INTOG)	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
High case	Number of FLOW Units	6	15	68	124	125	125	100	75	75	75	88	100	113	125
Low case	Number of FLOW Units	6	9	18	89	75	75	50	50	50	50	63	63	63	63

Celtic Sea Regional Integration Port Facility Requirements up to 2040

(number of integration ports required per annum based on the annual deployment rate)



SCENARIO	CELTIC SEA	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
High case	Number of FLOW Units	3	15	15	45	38	38	38	38	38	50	50	50	50	50
Low case	Number of FLOW Units	3	6	12	30	25	25	25	25	25	25	25	25	25	25

To prepare for industrialised deployment and limit uncertainty in viability of concrete substructures, more clarity needs to created on design envelopes and required port practices

Port capacity need: Concrete manufacturing & steel assembly ports

Concrete substructure manufacturing port

Up to 2030 projects are expected to utilise different substructure concepts. Therefore it is very unlikely that centralised port facilities, either regionally or nationally, would be utilised to manufacture concrete substructures.

Beyond 2030, as substructure concepts consolidate, then the provision of centralised port facilities to produce substructures for multiple projects would help to drive the industrialisation process with related efficiencies in cost. **If these floating turbines need to be deployed on an industrialised scale in 2030, the substructures need to be produced/manufactured before that time. This implies that port infrastructure needs to be in place in 2028-2029 to manufacture and transport substructures before integration and deployment in 2030.**

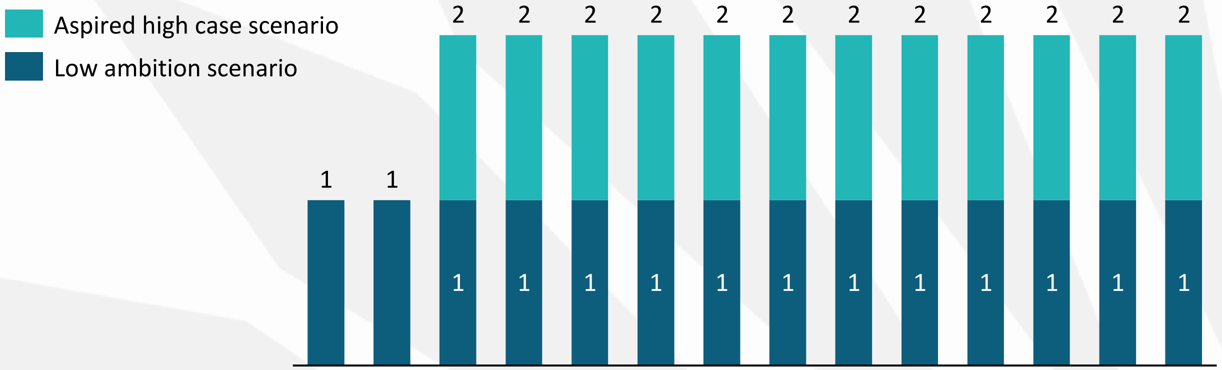
For the 3GW scenario, neither region in isolation has sufficient deployment numbers to require industrialised scale concrete manufacturing facilities (50 units annually) but the **combined numbers would justify an industrialised scale facility nationally from 2030.**

For the 5GW scenario, the deployment numbers in Scotland would support an industrialised scale concrete manufacturing facility regionally but the deployment numbers in the Celtic Sea would not yet as the region is in a different level of development. **Combined deployment would support 2 industrialised scale facilities nationally from 2030.**

It should be noted that **concrete might have a slower development curve, compared to established steel practices**, as there will be a need to test substructures before going to commercial scale. Unless proven technology emerges as part of early stage deployment a lag in concrete could be expected.

Concrete Substructure Facility Capacities to serve FLOW Deployment Nationally up to 2040

(number of concrete substructure ports required per annum based on annual deployment rate)



*Concrete Substructure Facility Capacities to serve FLOW Deployment in **Scotland** up to 2040*

SCENARIO	SCOTLAND (Incl. INTOG)	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
High case	Number of FLOW Units	3	7	34	62	63	63	50	38	38	38	44	50	56	63
Low case	Number of FLOW Units	3	5	9	45	38	38	25	25	25	25	32	32	32	32

*Concrete Substructure Facility Capacities to serve FLOW Deployment in **Celtic Sea** up to 2040*

SCENARIO	CELTIC SEA	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
High case	Number of FLOW Units	2	7	7	22	19	19	19	19	19	25	25	25	25	25
Low case	Number of FLOW Units	2	3	6	15	13	13	13	13	13	13	13	13	13	13

Steel components are seen as an essential part of FLOW industrialisation and infrastructure for industrial scale deployments needs to be ready in 2028 – 2029

Steel substructure assembly port

Up to 2030, projects are expected to utilise different substructure concepts. Therefore, it is very unlikely that centralised port facilities, either regionally or nationally, would be utilised to assemble steel substructures.

Beyond 2030, as substructure concepts consolidate, then the provision of centralised port facilities to produce substructures to multiple projects would help to drive the industrialisation process with related efficiencies in cost and programme.

For the 3GW scenario, neither region in isolation has sufficient deployment numbers to require industrialised scale steel assembly facilities (50 units annually), but the combined numbers would justify an industrialised scale facility nationally to be ready for use before 2030.

For the 5GW scenario deployment numbers in Scotland would support an industrialised scale steel assembly facility regionally, but the deployment numbers in the Celtic Sea would not yet support this. **Combined deployment numbers would support 2 industrialised scale facilities nationally from 2030. Both scenarios will require facilities to be in place 1-2 years prior to deployment for successful manufacturing, integration and timely deployment.**

Regional steel substructure assembly port capacity

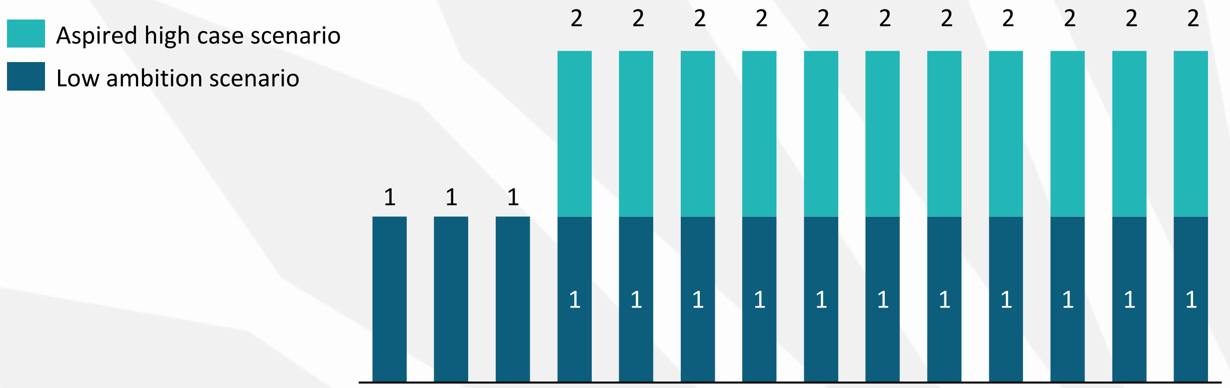
In Scotland, no current port facilities were identified in the region that fulfilled all of the infrastructure requirements for an industrialised scale concrete manufacturing or steel assembly facility. **7 ports were identified in the Scotland region which could be developed to provide industrialised scale manufacturing and assembly facilities.**

For the Celtic Sea no current port facilities were identified in the region that fulfilled all of the infrastructure requirements for an industrialised scale steel assembly or concrete manufacturing facility. **3 ports were identified in the Celtic Sea region which could be developed to provide industrialised scale manufacturing/assembly facilities.**

An additional 5 ports were identified outside of the Scottish and Celtic Sea regions which could be developed to provide industrialised scale manufacturing/assembly facilities to support deployment of FLOW.

Steel Substructure Facility Capacities to serve FLOW Deployment Nationally up to 2040

(number of steel substructure ports required per annum based on annual deployment rate)

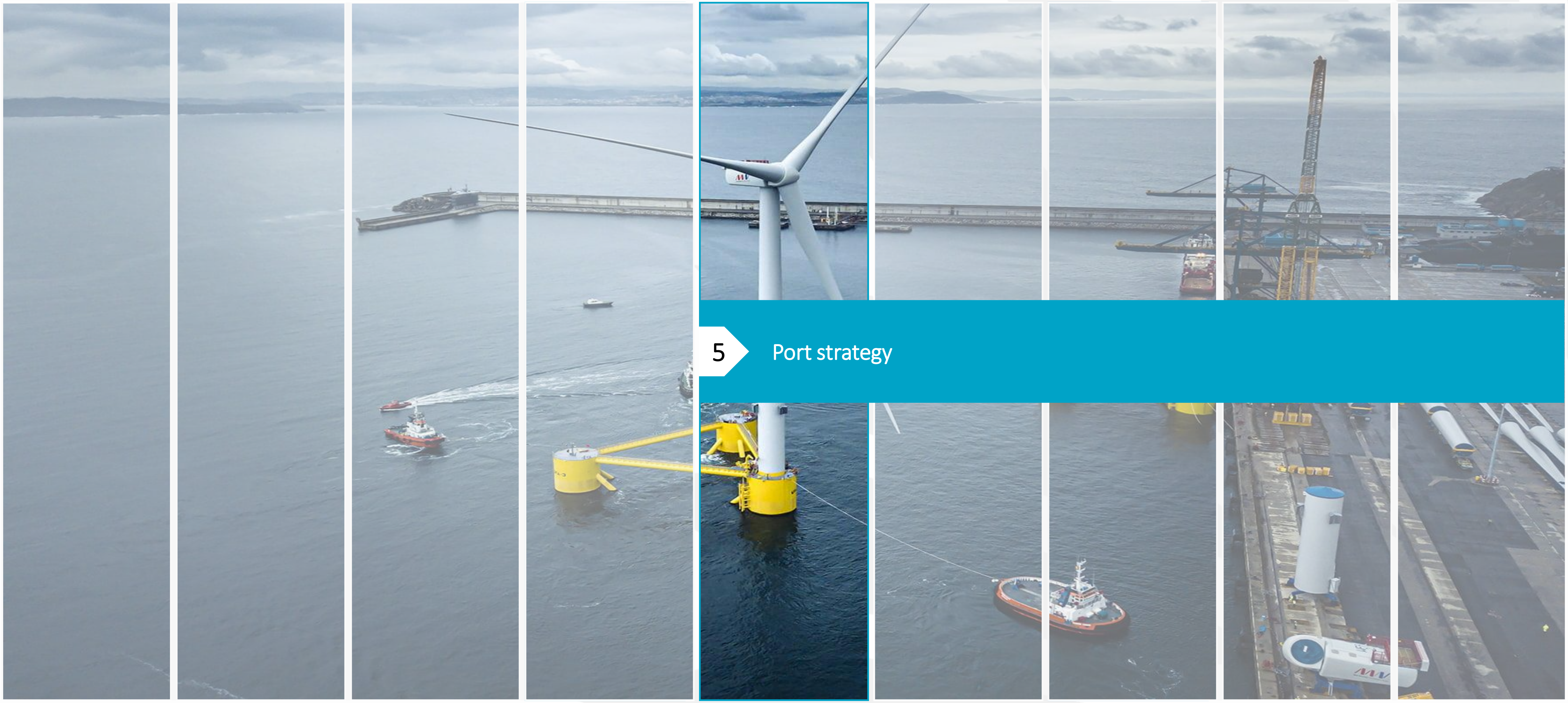


*Steel Substructure Facility Capacities to serve FLOW Deployment in **Scotland** up to 2040*

SCENARIO	SCOTLAND (Incl. INTOG)	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
High case	Number of FLOW Units	3	7	34	62	63	63	50	38	38	38	44	50	56	63
Low case	Number of FLOW Units	3	5	9	45	38	38	25	25	25	25	32	32	32	32

*Steel Substructure Facility Capacities to serve FLOW Deployment in **Celtic Sea** up to 2040*

SCENARIO	CELTIC SEA	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
High case	Number of FLOW Units	2	7	7	22	19	19	19	19	19	25	25	25	25	25
Low case	Number of FLOW Units	2	3	6	15	13	13	13	13	13	13	13	13	13	13



5

Port strategy

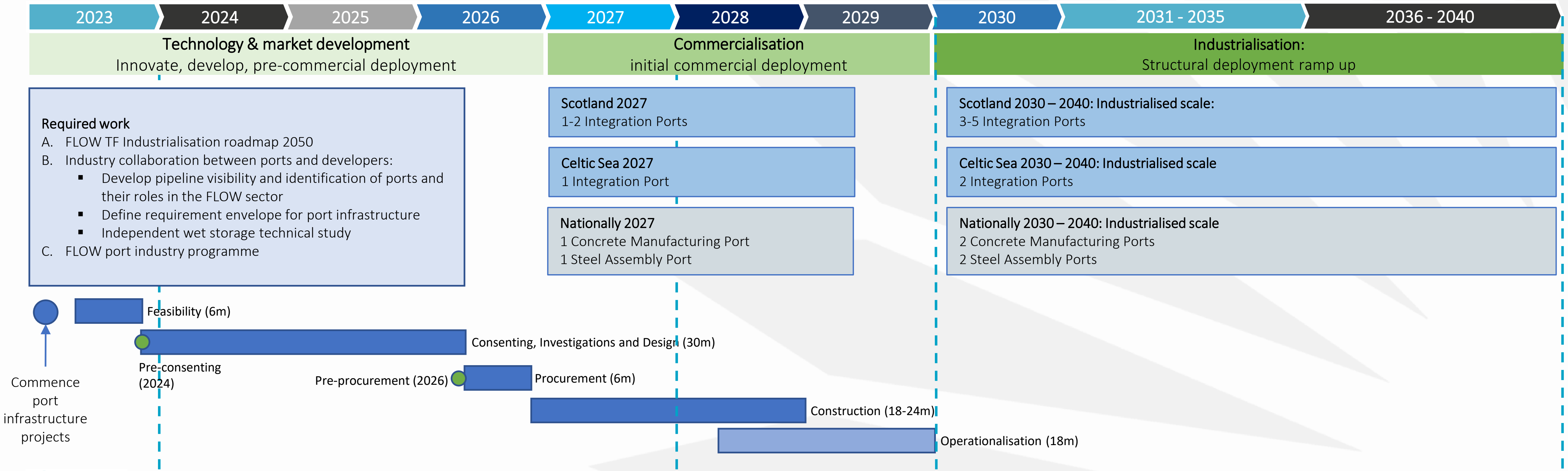
Image source: GWEC

As port capacity is not able to deliver expected deployment, the time to act is now. Especially since initial deployment years serve as period of proof for feasibility of industrialisation

Timeline squeeze

Current port project developments and investments are not coming off the ground at the required pace unless a more central strategic and coordinated approach is chosen. The timeline towards 2030 is tight and it seems impossible to deliver on our ambition if prompt action is not taken. The combined development time of ports from commencement to construction (up to 4-5 years), and an **assumed operationalisation of 18 months,** does not seem to fit the timeline of when port infrastructure for industrialised scale has to be operational. **The time to act is now,** especially when the years of initial deployment (2027 – 2029) need to serve as period of proving the feasibility of industrialised scale deployment. **Initial future proof and scalable port infrastructure investments need to get off the ground now to be in time and to encourage and accelerate investments over time.**

Port infrastructure investments and support should be two-fold. **Firstly,** on imminent action by directing investment support towards facilities that are able to optimally serve initial commercial deployment by limited modifications or infrastructure additions, and from there they can further develop as a specialist or larger hub on industrialised scale. This will assure initial deployment and kick-start commercialisation and future investments in those ports. **Secondly,** the focus should be on investing in identified key ports that should serve as 1) industrialised scale integration ports in the region, and 2) optimal manufacturing and assembly facilities on a national basis. This two-fold approach stimulates a multi-port approach that combines specialist ports with larger integration hubs.



2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 - 2035 | 2036 - 2040

Technology & market development
Innovate, develop, pre-commercial deployment

Commercialisation
initial commercial deployment

Industrialisation:
Structural deployment ramp up

Required work

A. FLOW TF Industrialisation roadmap 2050
B. Industry collaboration between ports and developers:
  - Develop pipeline visibility and identification of ports and their roles in the FLOW sector
  - Define requirement envelope for port infrastructure
  - Independent wet storage technical study
C. FLOW port industry programme

Scotland 2027
1-2 Integration Ports

Celtic Sea 2027
1 Integration Port

Nationally 2027
1 Concrete Manufacturing Port
1 Steel Assembly Port

Scotland 2030 – 2040: Industrialised scale:
3-5 Integration Ports

Celtic Sea 2030 – 2040: Industrialised scale
2 Integration Ports

Nationally 2030 – 2040: Industrialised scale
2 Concrete Manufacturing Ports
2 Steel Assembly Ports

A firm port development strategy that moves away from the project-by-project approach is required to assure timely operationalisation of a critical level of infrastructure

Strategic port development options

The apparent time squeeze to develop long-term port capacity for FLOW combined with the identified bottlenecks indicate that significant and coordinated port developments are required. **This seems to only be feasible if more centralised steering, guidance and agreement is established** on the certainty and timing of the project pipeline and if technologies as well as work method standards are exchanged, port investments prioritised, port design envelopes and potentially designated key port locations determined. This will assure that technology maximises the facility efficiency and new technology will fit to the facility.

This points towards a national strategic approach to port development, which would imply that the industry needs to move away from current market practice of a project-by-project port approach. A more strategic approach of optimally combining and developing port infrastructure to service multiple projects throughout the UK is needed.

Current practice: project-by-project

Properties

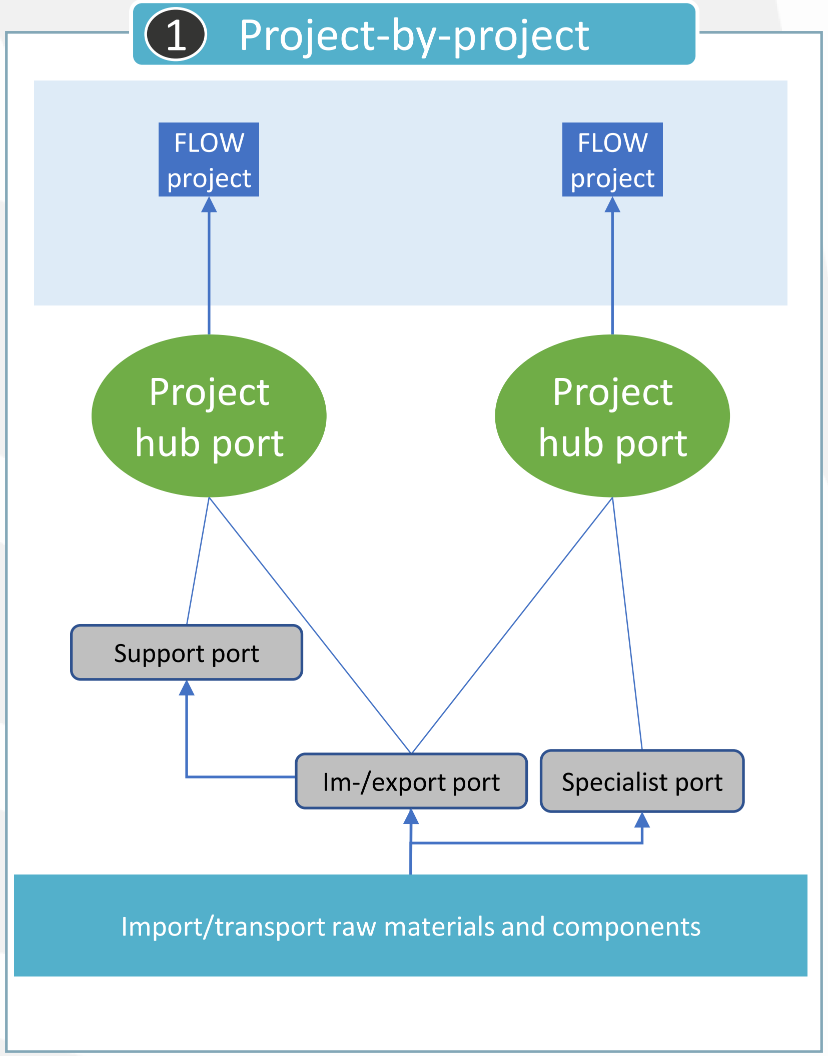
A project-by-project development is seen as current market practice in fixed bottom wind and FLOW projects in development. These are project led port developments in line with specific project requirements, needs and commercial viability. These ports are often in project proximity and chosen to optimise project efficiency for developers. Securing port capacity specifically for projects entails combining port infrastructure based on available or potential port specifications, stimulated by available supply chain options. Projects are then serviced by specialised and support ports (in the UK or abroad) to complete the project supply chain requirements.

Pros

- Developed from a commercial perspective with financial viability
- Facilities are optimised for the project, making designs to match the industry needs
- Project focused developments are an important first step and enabler for long-term developments
- Installation processes and infrastructure facilities can be tested and develop into best practices on a project level

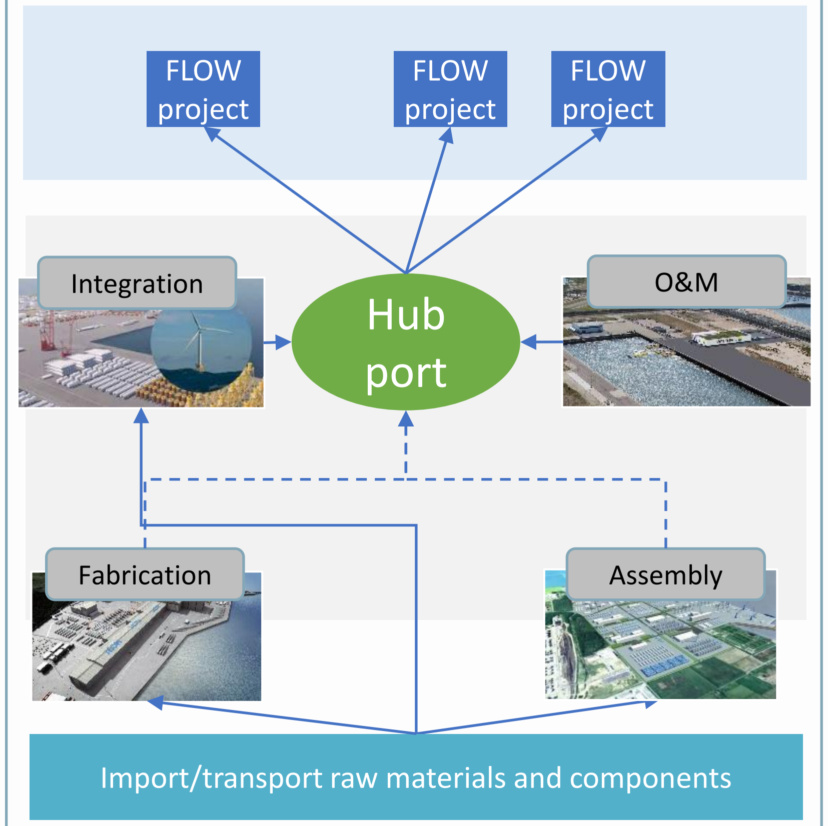
Cons

- Developments are single project focused so they could be suboptimal from a market or multi-project point of view
- There is a limited amount of (structural) collaboration and development of standardisation
- The use and development of other offshore wind / FLOW specialised and experienced ports is limited
- Individual set-ups for each project mean that more port facilities are required to achieve the deployment aims
- Weaker business case for port development as development time scales will be very short



Developing large hubs that take on multiple roles can increase efficiency, scale and viability, but they require significant infrastructure and investments while risks increase

② Big hubs



Properties

A strategy focus on developing larger centralised hubs is based on developing large and combined facilities in the deployment regions in proximity to projects. These will be multi-functional ports that will combine a mix roles of manufacturing, fabrication, integration and/or O&M. Potentially in combination with other markets like offshore O&G, decommissioning and fixed bottom offshore wind. These large hubs predominantly based on their competitive position in the regional but could create a beneficial position on a national and European level. One example is the Port of Esbjerg, which is a world leader in offshore wind activities by being a key link between production and offshore wind sites in surrounding waters, and providing pre-assembly, access to installation vessels and O&M.

Pros

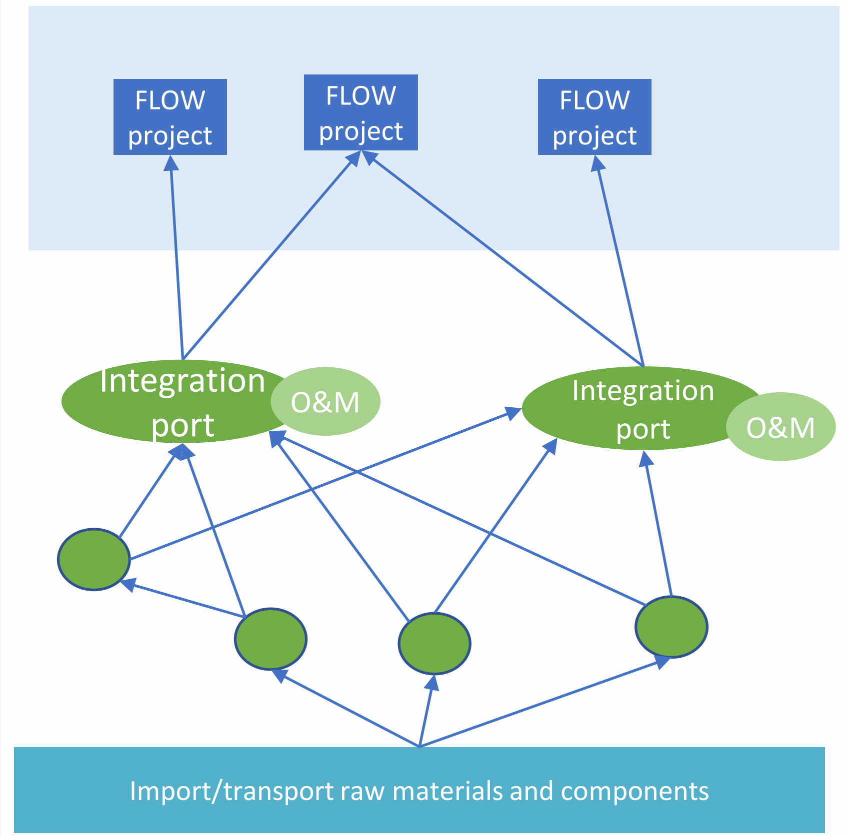
- Optimal combination and efficiency due to combined port roles in one large facility
- Development of a local supply chain, skills and regional economic benefits are stimulated
- Developing potential combinations with other markets could improve business case and investment attractiveness
- Large hubs could position effectively for cross-border projects
- Larger hubs could be attractive for European supply chains and contractors, which supports securing supply for UK projects
- Large scale port development in line with expected industrialisation required scale and port infrastructure

Cons

- Large hubs could act as a single port of failure due to site specific and disaster risk
- Focus on hubs will enable winners but also excludes ports and limits other ports from playing a role, while they are probably required to play role on large scale deployment
- The competitive position mostly based on project proximity and/or regional position, more limited view on national or European competitive position
- Specialist ports will be less developed
- Need for more local integration and O&M facilities missed
- Conflicting interests from individual projects could lead to capacity and use case issues
- Using larger central hubs could lead to less optimal and longer tow distances for projects
- Large hubs require large investments, with a risk of over investment and temporary under-utilisation of costly or non-competitive facilities

A multi-port strategy is strongly advised as it provides an optimal combination of integration, manufacturing and specialist ports that services jointly determined technology and projects

③ Multi-port



Properties

A multi-port approach is the most advanced strategic approach, and is focused on a more coordinated, collaborative and central led port development. On a national level, a multi-port strategy can be developed based on finding the most attractive and efficient way to combine and share port facilities for a set of multiple projects. The aim is to create synergies, stimulate a common build strategy and to service multiple projects and other markets in different combinations. In a multi-port strategy integration ports are most likely to be in the region close to projects, in combination with O&M. While fabrication/manufacturing/delivery/support ports based can play a specialist role and develop a competitive position on a regional, national or European level. As part of an integrated multifunctional port arrangement, ports with less infrastructure – ideally nearby – should target assembly works, taking components or partially assembled subcomponents from the other specialist ports. This allows developers and Tier 1 suppliers to use the port without being constrained by in-situ fabrication.

Pros

- Optimise port use, facility development and project demand
- Creates a network of ports that includes a large variety of ports that can play their part
- Spread and phased investments
- Creates flexibility in the supply chain
- Leaves room for future entrants and capacity
- Developing a multi-port strategy could accelerate synergies, industry practices and standards
- Reduction of risks and limits single point of failure
- Component manufacturing opens export opportunities, competitive and automated supply with proven technology will be recognised and used by developers outside the UK
- Developing a multi-port strategy would imply spreading economic benefits and the skilled work force need regionally, reducing scarcity constraints and spreads economic impact

Cons

- Complexity in determining best approach and creating requirement clarity
- Willingness of market players to work together and potentially giving away preferred position
- Demands more central decision-making and working on a common port goal, which might be difficult to implement

Considering the port development task at hand, it seems apparent that continuous financial support should be in place to assure port infrastructure is developed over time and in time

Financial support options

FLOWMIS is seen as a key financial support mechanism to kick-start business cases for FLOW port infrastructure by increasing the financial feasibility of investments. The fund will be made available for investments in port and manufacturing developments that scale-up deployment to meet FLOW ambitions and the wider net zero objectives. **There has been a high level of interest from the port sector and the UK Government is expected to set out the next steps on FLOWMIS soon**

Considering the substantial port investment task at hand, it seems apparent that a one-off FLOWMIS fund will be insufficient and not enough to secure the essential funding that will assure the required port infrastructure is developed in time for FLOW deployment. FLOWMIS support should continue as far as possible, and additional investment options beyond FLOWMIS are needed to service the two-folded goal of developing facilities for the early deployment years and for industrialised scale.

Based on the success of and lessons learned from OWMIS and FLOWMIS, a **continuous or recurring financial support scheme** should be in place. This instrument would need to evolve in line with identified key bottlenecks from the application rounds and support needs at the different stages of sector and infrastructure development.

Freeports

Freeports are special economic zone ports which offer tax reliefs, attractive business retention rate guarantees, relaxed customs arrangements, and get support in terms of planning, innovation, seed capital.

Currently there are 8 Freeports in England and 3 bids for a Freeport in Wales, of which 2 are public bids from Celtic Freeport with ABP, Talbot and Milford and Stena Line Holyhead Port. Two sites are currently under development in Scotland.

Early 2023, Inverness and Cromarty Firth Green Port and Forth Green Port have successfully bid for a new Green Freeport, backed by £52mn of UK Government funding. These new sites are expected to bring forward an estimated £10.8bn of private and public investment.[1] **Both ports focus on playing a role in FLOW by means of integration and renewable manufacturing, with Freeports providing a potential support option to accelerate FLOW related port infrastructure investments.**

In the initial stages of FLOW and port development, a more mission driven investment focus needs to be stimulated and accelerated by means of public-private partnerships and funding to advance the sector to commercial stages of full commercial investments.

The financial support will not only require sufficient funds over a longer period of time, but would be most effective if it also entails the use of **government influence, expertise and instruments to secure both public and private funding.** This will support pre-commercial viability and acceleration in port infrastructure investments.

Besides direct seed funding, additional investment support could focus on a) unlocking public infrastructure development bank funds and long-term capital, b) coordinating and connecting public-private investments, c) linking transport or supply chain infrastructure investments by considering network effects, or by d) increasing certainty of projects by assuring or underwriting revenue streams over time.

The UK government and regional public bodies could also develop and **support a structured collaboration between groups of FLOW developers and port owners**. This would allow the industry to focus on their common interest to identify, develop and potentially share port infrastructure facilities. This could help mobilise and bundle funding in a strategic investment approach to get projects off the ground. An example is SOWEC’s Strategic Investment Model (SIM), which focuses on collaboratively identifying and **prioritising most strategically important investment opportunities, bundling investments and sharing risks** (further information can be found in the appendix).

The government could also expand and firm the options to accelerate investments for FLOW in Freeports with increased focus on FLOW focused port facilities as well as by setting specific requirements for attracting FLOW manufacturers and developers to the ports. This will potentially strengthen attractiveness for private investments in the Freeports.

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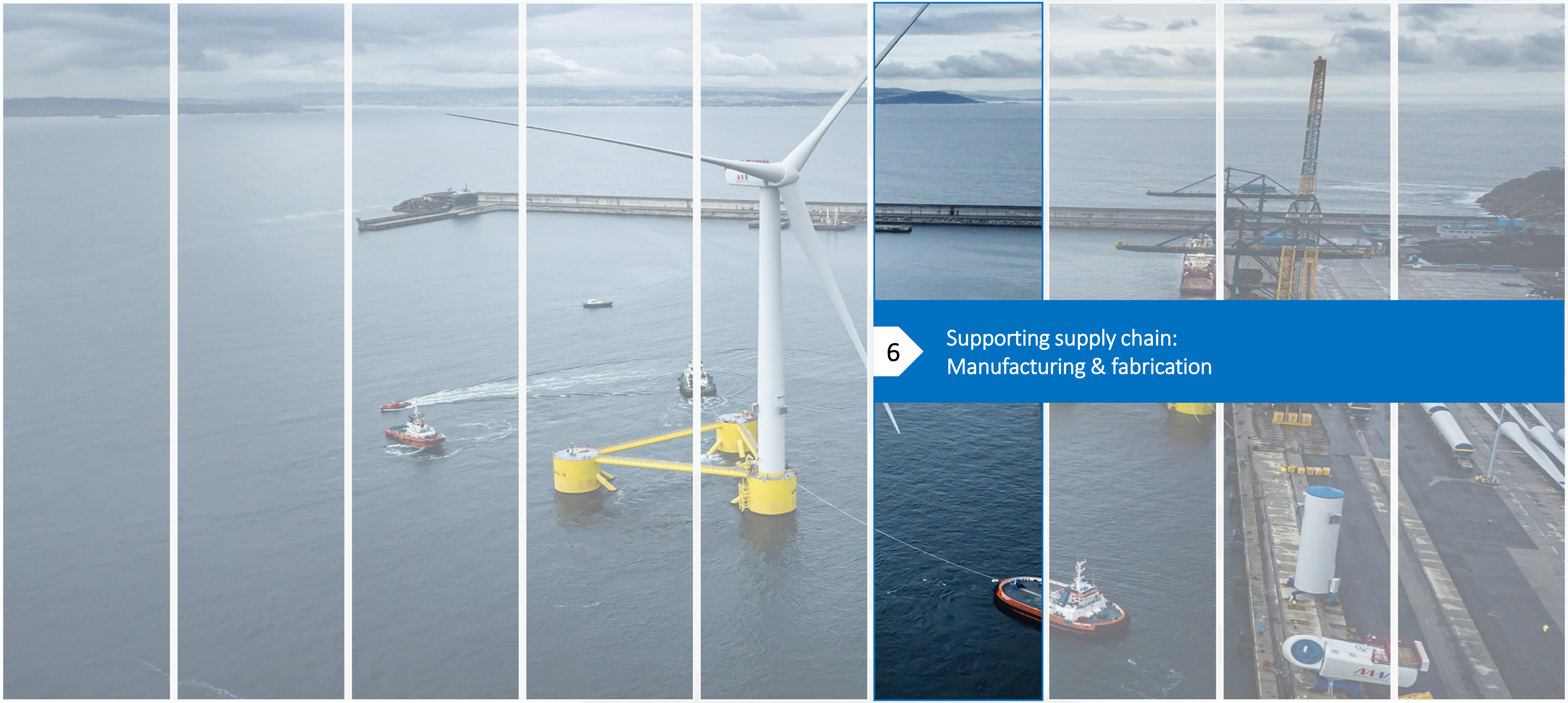
[1] Source: UK Government,13 January 2023 “Joint cooperation to deliver two new Green Freeports in Firth Of Forth and Inverness and Cromarty Firth”



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Supporting supply chain: Manufacturing & fabrication

Image source: GWEC

The presence of a strong and reliable nearby supply chain and a logistically well connected ecosystem of local companies is critical to the success of FLOW ports

Manufacturing & fabrication

- Ports form the linking pin between manufacturing supplier, and the offshore installation and operation of FLOW throughout the asset lifetime. **The presence of a strong and reliable nearby supply chain and a logistically well connected ecosystem of (local) companies is critical to the success of FLOW ports**. This can be observed in, for example, offshore O&G clusters, fixed bottom offshore wind projects and the success of large industrial port areas. It secures supply and assures predictability of operations, cost levels, and supply chain efficiencies, synergies and innovations.
- Building up an offshore wind supply chain will deliver significant economic benefits to the UK economy. **Every gigawatt of offshore wind generates an estimated ~£2bn of economic value to a country[1] and offshore wind O&M is estimated to be worth ~£1.3 billion per year to the UK economy[2]**. Without the development of important supply chain activities in the UK at critical ports, valuable construction, supply and O&M activities will be missed.
- **For integration ports the handling, storage, assembly and hub function close to projects is more important than close-by fabrication facilities.** However, presence of a well connected UK supply chain of turbines, components, towers and moorings would benefit the position, efficiency and industrial scale development of integration port facilities. This can be further from the port to not interfere with integration and installation activities.
- **The technology and production of FLOW substructures still requires development and could potentially be a major bottleneck that could hinder the ambitions of deployment**. However, developing manufacturing and fabrication activities close to ports can benefit both FLOW deployment and improve the investment attractiveness of the port whilst elevating the role of the port in the value chain, enabling the capture of FLOW export opportunities. The success of the Port of Esbjerg in Denmark, which has gained a strong position in the supply chain in northwest Europe is partially due to its long-stand relationship with Vestas, demonstrates the potential benefits of this approach.
- For the purpose of this research, a selective FLOW assessment has been executed. Our aim was not to do a full supply chain assessment but to make a connection to the identified port infrastructure development focus. This enables us to formulate useful recommendations for attracting strategic manufacturing that will enable and strengthen UK port infrastructure developments and creates a stronger position for UK ports in the FLOW supply chain.
- **This section will briefly identify the broader industry opportunities but mainly focuses on developing substructure manufacturing and fabrication facilities in the UK to the benefit of port infrastructure developments and acceleration of FLOW deployment**. This section will not touch upon the development of local content in fabrication but does give a brief assessment of potentially attractive and critical FLOW fabrication components that would be strategically important to develop.
- An important consideration is that many of the FLOW sub-elements are not unique to FLOW. UK FLOW deployment is often, by itself, not a large enough demand to drive UK supply chain investment decisions on that basis. For common sub-elements, this can only be achieved by considering the cumulative fixed and floating demand profile, use for alternative markets and taking into account overseas opportunities. This could be an interesting but complex topic for future research.

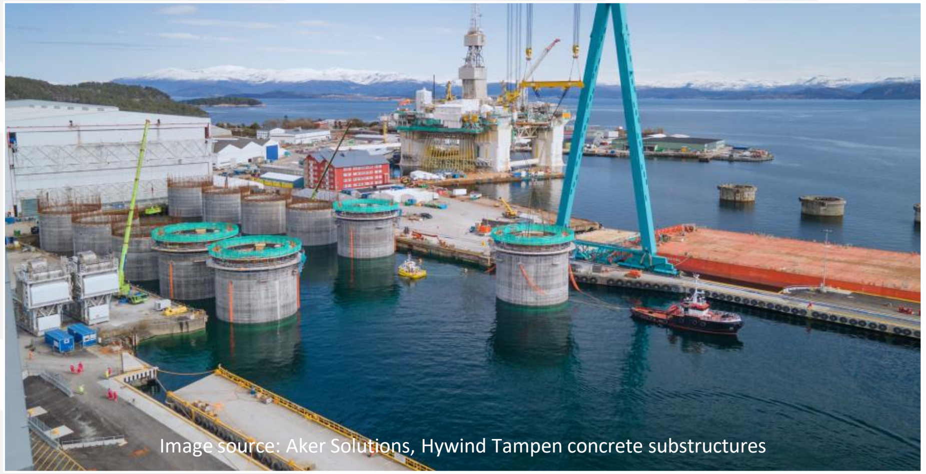
Image source: Aker Solutions, Hywind Tampen concrete substructures

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1) Source: WindEurope "Wind energy and economic recovery in Europe"
2) ORE Catapult "Three ways the UK offshore wind supply chain boosts the economy"

The FLOW manufacturing supply chain is based on a market dynamic of reputable wind OEMS and global suppliers. Attracting production will accelerate FLOW deployment in the UK

Supply chain dynamics

- The supply chain technology and components for FLOW is expected to be built further on existing dynamics in the onshore and fixed bottom offshore wind industry. A limited number of established players in turbine, electrical components, and cable manufacturing companies will continue to diversify and service the FLOW market. These OEMs have their own in-house supply chain and often a network of qualified partner suppliers to deliver materials and components.
- The market and technology concepts for FLOW substructures are still in development. This will provide opportunities to existing concrete and steel manufacturing players to develop attractive and competitive (modular) designs and facilities to service both the national and European market.
- The more fragmented supply chain for smaller components, towers, castings, moorings and anchors are generally more cost-driven supply markets. These supply chains are driven by Global or European players with often multiple production locations to assure presence in key offshore wind markets.
- Attracting local OEMs and specific supply chain activities for key components, suppliers or a diversification of options for FLOW projects will be beneficial to the cost, technical feasibility and deployment of FLOW. A proactive approach in deliberation with developers, suppliers and ports by the UK Government to attract specific FLOW production would accelerate FLOW's commercial viability and deployment.

	Turbines (rotors, blades, bearings, gearboxes)	Electrical components (controls, generators)	Towers & castings	Foundations & substructures	Cables	Moorings & anchors
Market concentration	Highly concentrated market with a select number of large turbine suppliers with a diverse in-house global supply chain.	Highly concentrated market for control systems. Generator market is more fragmented and outsourced.	Highly fragmented and outsourced market.	Highly concentrated market with selective number of fabricators.	Highly concentrated market with a limited amount of subsea cable manufacturers.	Highly fragmented market based on existing mooring and anchor capabilities and production from offshore activities.
Market dynamics	Limited amount of large OEMS dominant in offshore wind. High quality supply chain of qualified and partner companies.	Large independent suppliers and in-house sourcing for control systems. More outsourcing for generators but limited amount of qualified suppliers for large sizes.	Larger amount of suppliers often regionally selected. Cost competitive market.	Larger global suppliers who are able to deliver large steel and concrete structures. Sourced from Europe but more often from low cost locations (Far and Middle East).	Limited amount of market players and clear market leaders for cable manufacturing with global production.	Large amount of suppliers, commoditised market. Scaling of FLOW could reduce number of qualified suppliers.
Market players (examples, non-exhaustive)	• Turbines: MHI Vestas, Siemens Gamesa, GE, Goldwind, Envision, Mingyang, Shanghai Electric • Components: LM Wind Power, SKF, ZF, NTN	• ABB • Winergy • GE • Emerson • Mita Teknik • Siemens	• CDMG • Faccin • Haizea Wind • EEW • Navantia • SIF • Sakana • GRI Renewables • Smulders	• Steel producers in offshore wind: Lamprell, Arcelor, EEW, Bladt, Eiffage, Smulders, Rosetti • Concrete: Aker solutions, Acciona, Bouygues and other large civil contractors	• NKT • Prysmian • Nexans • Hellenic cables • JDR • TKF	• Subsea Energy Solutions • MacGregor • Vryhof • IHC • First Energy • Dynamica • Bardex Corp.
Entry barrier	**High barrier** due to capital intensive nature and established OEMs. **Local supply chain or production locations possible.**	**High barrier** due to established market players and limited amount of qualified suppliers for large turbines.	**Medium barrier** due to capital intensive nature, but **production for regional or national purposes is possible** depending on cost.	**Medium barrier** due to capital intensive nature of fabrication, could **be built based on existing steel or concrete fabrication capabilities.**	**High barrier** for developing OEM role **Local supply chain or production locations possible.**	**Low barrier:** current suppliers would be able to diversify.

Source: RHDHV expert analysis

Some OEM activities are present or expected in the UK. Expansion of manufacturing depends on UK market demand and attractiveness, and the ability to progress innovative and standardised production

UK supply chain position

Turbines

The UK has existing capacity for blade production, which will supply both fixed and floating offshore wind projects. With two existing facilities that will be supplemented by further OEM capacity investment and new entrants establishing additional UK capacity for turbine manufacturing. Developers have referred to plans for increased levels of procurement from expanded or newly established UK OEM facilities.

The UK has no nacelle manufacturing capability, which is unlikely to change. There are currently no signals that OEMs have shown interest to localise in the UK.

Growing global demand from fixed and floating could create supply issues and a potential bottleneck for deployment in the UK. Attracting turbine manufacturing to the UK will generate significant commercial opportunities and will be instrumental to the success of both FLOW, and fixed bottom offshore wind in the UK

Turbine towers

Tower fabricators could focus on full towers but also have the potential to supply tubular or modularised substructure concepts. The UK currently has no tower OEM capability. There are plans for a local investment in the UK to establish an automated tower OEM production facility, with talks ongoing and FLOW developers expressing commitment to use it. Some developers have indicated a plan to procure towers from a new UK OEM facility.

Local tower production could ensure supply and lower cost, depending on the ability to set up a cost competitive facility that can service both UK and European markets.

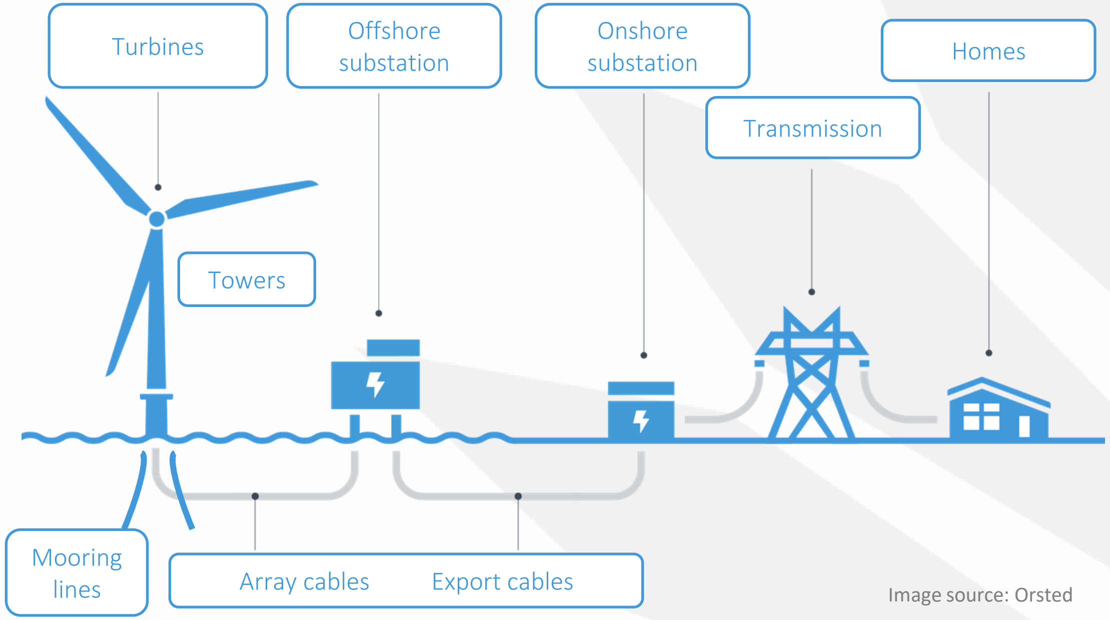


Image source: Orsted

Moorings and anchors

Mooring and anchors represent an existing industry with a new application in FLOW. The UK is well-placed to deliver a supply of mooring, anchor systems and offshore tensioning solutions based on a strong historical track record of acting as a mooring muster point for the North Sea O&G sector, which attracted mooring OEMs over time. The challenge UK suppliers will face is the need to develop innovative production solutions while remaining competitive in a cost-conscious market.

The availability of mooring chains is a known supply chain pinch point globally, and therefore the development of synthetic solutions are a key area of focus in FLOW aspirations beyond 2030.

Developers recognise that the UK capability in this area can be leveraged, and that overseas new entrants can be encouraged to establish new capacity in the UK. There is a strong appetite to develop mooring activity in both Scotland and the Celtic sea in anticipation of a thriving offshore wind market.

Substations

The UK has a track record of offshore substation topside supply, but the suppliers concerned have since exited offshore wind leaving the outlook limited. **These large structures are likely to be produced overseas and will be transported to its location for offshore hook up.** Predominantly they will be fixed rather than floating, looking at requirements and cost competition.

The UK is well-served in terms of onshore substation civil works contractors, therefore this activity is expected to take place in the UK.

Cables

The UK currently has one active array cable OEM and no high-voltage export cable capability. Further investment in existing array capability has been confirmed and the business case for new UK capacity is currently being discussed and developed. Ambitions to procure an increased level of cables from expanded and newly established UK OEM facilities (nominally assumed as JDR and Sumitomo respectively).

Although FLOW will drive a new demand for dynamic cables, supply will come from existing fixed offshore wind static cable OEMs, driving a competitive capacity situation between fixed and floating projects. Dynamic cables will drive new demand for quick-release connectors and buoyancy assets where the UK is well-served in terms of capacity.

Source: RHDHV and Scotia Supply Chain industry analysis

To build up capacity in the UK, substructures should be based on a standard modular and fully industrialised designs that can be mass produced at multiple locations within the UK supply chain

Substructure capacity & capability

- **There is currently no single design for a 15-20MW turbine that would suit all locations, environmental conditions and water depths while giving an optimum levelised cost of energy. It is unlikely that concepts will be consolidated before 2030.**
- **Towards 2040 a variety of options or industry standards are expected to emerge based on project suitability, ease of and efficiency in manufacturing, and national, regional or developer preferences.**
- Whereas turbine and substation topside designs are very similar for fixed and floating offshore wind projects, the FLOW substructure supply is extremely different. Whilst the same OEM capacity will likely be used to produce steel substructures for both technologies, concrete designs are a new type of application.
- Currently there are both steel and concrete concepts and there is a high probability that both or even hybrid versions will be utilised offshore the UK. The use of steel will be in line with common market practices in offshore O&G and fixed bottom offshore wind. There are also viable concepts for concrete substructures, but it is not clear how many developers prefer these concepts and how suitable they are.
- The majority of the developers have not stated a clear preference between concrete and steel. This is because for some countries or regions, it could be cost-beneficial to use either concrete or steel substructure based on existing capabilities and competitive position. Moreover, the fast growing global demand from both fixed bottom offshore wind and FLOW could require both concrete and steel supply chains to be developed which could offer solutions optimal for specific projects.

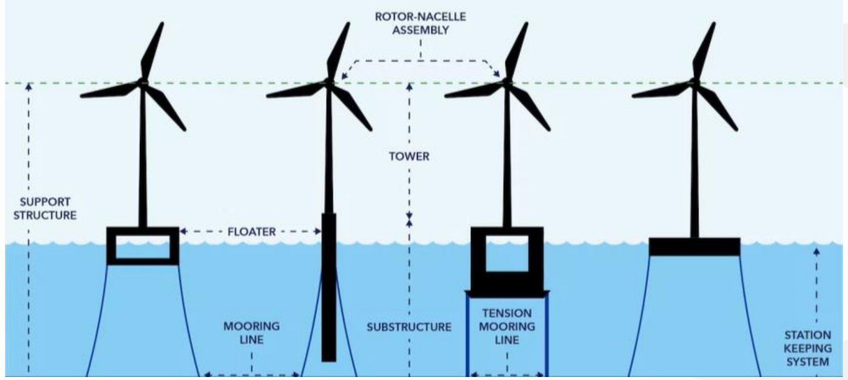


Image source: DNV

Steel

- The UK has a track record of building large substructures for the O&G industries and moderate steel jacket capabilities. This has reduced to very few projects in the last two decades and most of the supply has come from overseas – largely from Far & Middle East – as UK contractors have not yet been able to compete on price. Hence, UK fabrication investment is necessary to secure supply for the expected deployment. Dedicated FLOW fabrication capacity is unlikely to materialise pre-2030 due to the modest size of the UK market and the cost and supply challenges the UK is currently experiencing.
- According to the *UK Foundations Strategic Capability Assessment conducted by ORE Catapult in 2020*, UK and European delivered steel fabrication is estimated to be 10-15% higher than lowest global market prices. There is a risk that overseas manufacturing could limit the UK to final assembly works only if the government does not apply the interventions to increase UK competitiveness.
- **Overall, developing UK steel fabrication would require significant investments**. Steel manufacture technology also requires fabrication facilities and a skilled workforce that is not currently available in the UK. Finally, the steel producers in the UK will need early visibility of demand of FLOW plate grade, thickness and dimensions to increase capability in accordance with what is required.

Concrete

- The case is different for the emerging concrete substructure supply market, where local fabrication is more logistically advantageous and where the existence of a mature construction industry means the technical barriers to entry are lower. This means, when compared to steel, concrete seems attractive due to the transferability of the conventional construction skill set and the availability and reduced volatility of raw materials. It would however still rely on extensive pre-casting sub elements or continuous slip forming and investments in specialist equipment.
- Developing early FLOW demonstrators could give the local supply chain a ‘first mover’ advantage, demonstrating capability and capacity, and gathering experience that would enable supply chain development to service larger commercial sites.

The four principal substructure designs can be industrialised to varying degrees for ease of manufacture and fabrication. **To efficiently utilise and build up the existing capacity in the UK, it is important that substructures are based on a standard modular and industrialised design that can be mass produced at multiple locations within the UK supply chain and assembled easily at the port of departure to field.**

Turbine, cable and mooring production are of high value to build up in the UK. Advancing substructure manufacturing and fabrication is critical to FLOW deployment and port competitiveness

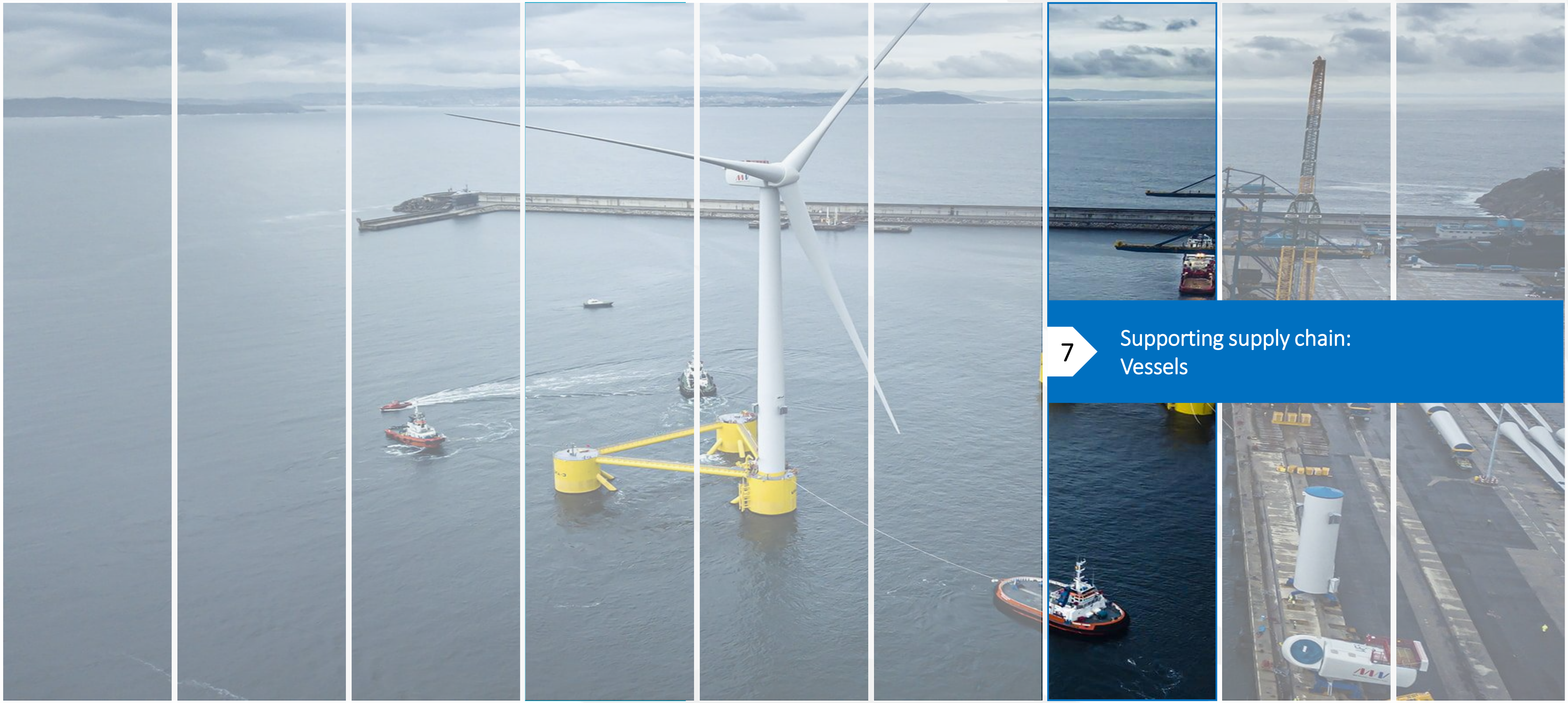
Strategic supply chain development

- **This roadmap is not about local content creation but about assessing development of the necessary infrastructure and supply chain activities needed to underpin the FLOW industry. Local content information, however, can be a useful tool to detail which parts of the supply chain are already strong and which areas need interventions to grow.**
- Baseline analysis published by BVG associates on behalf of the Scottish offshore Wind Energy Council (SOWEC)[1] in 2021 suggests that UK content on fixed foundation projects is around 46% (2020). The local content estimations on two initial Scottish floating projects was significantly less but the baseline analysis suggests that FLOW has the potential to exceed the fixed bottom offshore wind target of 60%.
- **The following conclusions can be drawn when combining the local content approach with the identified critical FLOW supply chain activities and the current position of the UK, as assessed in the table:**
  - **Development & Operation:** The UK is well established in both the development and operational stage of offshore projects, which needs to be maintained and expanded for FLOW to assure progress and operations on industrial scale.
  - **Installation:** UK's position is limited to secondary construction work, support services, or a representation for local operations of global main contractors. This will be elaborated on in the next chapter, but this seemingly only creates room to develop a support position.
  - **Manufacturing and fabrication:** In the supply chain there are some important components that are moderately established and of strategic importance to attract and grow: Turbine, cable and mooring related activities. The development of steel fabrication or concrete manufacturing has already been identified as essential, and dedicated FLOW facilities need to be developed to successfully strengthen UK manufacturing and assembly ports.
- **All-encompassing FLOW manufacturing and fabrication facilities should develop in line with the identified port capacity need, in order to concentrate investment, demand, benefits and skills.** These facilities have to appeal to various types of substructure concept providers and have to be flexible and focused on common and modular design elements.
- **The focus of UK OEMs should be on investing cost-competitive solutions via automation and investment in high-grade equipment so higher costs can be offset by efficiency.** The UK is well-served by a number of strong fabricators but these will need support to be able to supply the UK FLOW ports with the production level that are required to service the FLOW deployment

FLOW supply chain activities and UK content development options

Sub-element	Share of FLOW Cost[1] (%)	Estimated FLOW 2020 UK Share[1]	Current UK industry Position	Development focus	Reason
Development	2%	3%	Strong UK position	Maintain	Well established position, important to be in control of own FLOW developments and project management. No specific action required.
Turbine	19%	0%	Limited UK position	Attract	Turbines have a strategic value and are a key (cost) component. The UK should aim to proactively attract local turbine (component) production
Substations	3%	19%	Strong position	Maintain	Leverage existing track-record and expertise to optimise UK and overseas production capacity to assure supply.
Foundations & Moorings	9%	11%	Moorings strong	Develop & grow	The manufacturing of substructure components and moorings are specific to FLOW and will be of high strategic importance to develop FLOW at industrial pace and develop manufacturing port infrastructure in a competitive way.
Cables	2%	0%	Limited UK position	Attract	Expansion of current UK cable production facilities will strengthen the supply chain and secure supply but could also be sourced overseas as it is often installed directly from transport and installation vessels.
Turbine & Foundation Installation	6%	0%	Limited UK position	Secure capacity	The favourable position and strength of European main contracting companies limits options to develop a position. Focus on creating an attractive market to attract companies and assets.
Cable Installation	4%	11%	Production & support strong	Secure capacity	With the limited capacity of UK vessels and the relative strength of European main contracting companies, and cables generally being delivered directly to the project site; the UK opportunity is likely to remain limited.
Installation Other	3%	45%	Strong UK position	Maintain	The UK has a strong track record in quayside turbine tower assembly, general marshalling and offshore assembly and integration. Port development to service the size and scale of FLOW substructures for marshalling and assembly.
O&M	49%	86%	Strong UK Position	Maintain	The UK, based on historic offshore O&G expertise and the development of fixed bottom and early FLOW projects has provided the UK with a strong position for O&M of future FLOW capacity which need to be maintained.
Decom missioning	2%	30%	Strong UK position	Maintain	On the back of offshore O&G decommissioning activities, experience and adequate port infrastructure.
Total	100%	46%	🟧	🟩	*Maintaining and growing UK's current strongholds while developing strategic supply chain activities the local share is expected to increase.*

[1] Source: BVG Associates (2021) Reports for SOWEC on: Contractual terms and conditions in offshore wind; Centralised PQQ portal for UK Offshore Wind; SOWEC supply chain and procurement (awaiting publication by SOWEC)



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Supporting supply chain: Vessels

Image source: GWEC

7 Supporting supply chain: Vessels

The vessel spread needed for FLOW is existing technology available in the market. Next generation and dedicated vessels required to be built in line with growing demand and scale

Required vessel spread

- The installation of FLOW turbines transferring them from the port to mooring offshore, and ongoing operations & maintenance (O&M) by vessels after commissioning, is the final stage of deployment in the FLOW value chain.
- These vessels need access to the port, sufficient deep channels and berths, sufficient quay space and often a home base close to operations for bunkering, supplies, repair and maintenance. This has been taken in consideration for the port requirements.
- **The vessel market and requirements show a different dynamic from the fabrication and port infrastructure**. Differently from the onshore manufacturing and port industries, the offshore marine construction, shipping and shipbuilding industries are global private markets, driven by a globally spread supply and demand for offshore services. These players mobilise and deploy their vessels in strategic locations, either dedicated to specific project sites and regions, or tactically placed in multiple regions across the globe. Often those locations are close to their home markets or in maritime hotspots to minimise mobilisation and to secure presence and strategic (global) spread of assets.
- Beside the vessel owners and contractors, the shipbuilding industry has mostly shifted and established itself in Asia. Countries like China, South Korea and Singapore have asserted themselves as most cost-price competitive global players for shipbuilding. Shipbuilding in Europe is reduced to smaller specialised vessels, main equipment and supply production, and a limited number of shipyards are able to compete on the larger vessel and hull construction.
- **In general, the identified vessel spread needed to install floating offshore wind is available in the market and is expected to develop in line with growing market demand and FLOW turbine dimensions**. There will be challenges in dealing with increasing dimensions and weights, capacities (e.g. bollard pull) but in general the basic expertise and technology is available. The technology and assets are mainly built upon practices in offshore oil & gas, fixed bottom offshore wind and maritime transport, and can be developed further.

TOWING – Vessels to tow turbines to their offshore installation location
- Towing tugs - Ocean going towing tugs to tow FLOW turbines to site
- Escort tugs – Supporting tugs
- Anchor Handling Tugs (AHT) – Preinstall moorings and anchors, tow and hook up floating foundations, install dynamic cables

SUBSEA CONSTRUCTION – Vessels for offshore construction of FLOW
- Flexible Fall Pipe vessel (FFPV) – Cable protection and ballasting
- Cargo barge – Transport of rock material
- Subsea construction vessels for mooring (MPSVs)
- Cargo barge for transport and storage of mooring
- Optional / limited use: Dive Support Vessel (DSV)

CABLE INSTALLATION – Vessels for the installation of offshore cables
- Cable Lay Vessel (CLVs) for inter-array and export cables
- Crew Transport Vessels (CTVs)
- Cable burial vessel

SURVEY AND SUPPORT – Vessels for inshore and offshore construction support
- Survey vessels (SVs) – Geotechnical surveys and monitoring
- Patrol boats (PBs) – Support of offshore construction and operations
- Requirements for ROVs, diving or large construction vessels should be minimized
- Semi-submersible vessels – To support launching of structures in the port

TRANSPORT & INSTALLATION
- Heavy Lift Vessels (HLVs) needed for substation jacket and topside installation
- Jack-up Vessels (JUVs) for quayside turbine installation (optional in alternative to shore-based port cranes)
- Heavy Transportrt Vessels – Transport systems, structures and components from fabrication port to integration port

7 Supporting supply chain: Vessels

Considering UK's limited position in offshore contracting and shipbuilding, and in anticipation of potential supply shortages, efforts should focus on attracting critical FLOW installation vessels

Vessels availability and importance

🔴 Limited/ low 🟠 Moderate/ medium 🟢 Strong/ high

Phase	Vessel type	Indication of current vessel availability	UK position	FLOW Importance	Long-term availability
Transportation and mooring	Towing tug, escort tug, and multiple Anchor Handling Tugs (AHT)	28 towing tugs, at least 32 AHTs in Europe *Example companies: Damen, Boskalis, DOF Subsea, Heerema, Maersk*	🟠	🟢	🔴 Limited amount Increased FLOW requirements
Subsea construction	Flexible Fall Pipe Vessel (rock dumping vessel, minimal DP2)	8 advanced vessels, total fleet of 13 available globally *Example companies: Van Oord, Boskalis, DEME, Jan de Nul*	🔴	🟠	🔴 Limited fleet Competing demand
Subsea construction support	Multi-purpose (MPSV) vessels for construction support (also known as CSV) Diving Support Vessels (DSV)	49 MPSVs and at least 19 DSVs in Europe *Example companies: MPSVs: DOF Subsea, Technip, Subsea 7, Boskalis, Deep Ocean, Fugro, Jan de Nul, Nexans, Seaway Offshore Cables, DEME.* *DSVs: Boskalis, Subsea7, Technip, DOF, Havyard Group, Marshall Marine*	🟠	🟢	🟢 Large fleet and supply group Easy to expand
Cargo Barges	Cargo barges for rock material or transport/storage of moorings	Abundantly available, easily found through brokers Limited suppliers	🟢	🟠	🟢 Commoditised
Heavy Transport and semi-sub vessels	Large transport and support vessels used for transport of structures, jackets, vessels from one port location to another port location,	Limited amount of suppliers, global vessel capacity of 30-50 vessels *Boskalis (Dockwise), Subsea7, GPO, Cosco, Jumbo, BigLift, GRS, Krohne*	🔴	🔴	🟠 Sufficient vessels but high degree of competing demand
Cable Installation	CLV for inter-array and export (cable burial vessel with trenching and ploughing capabilities)	40 available CLVs and MPSV/CLVs globally *Example companies: Boskalis, Van Oord, DeepOcean, Jan de Nul, Nexans, Prysmian, Subsea7, NKT, Assodivers*	🟠	🟢	🟠 Limited fleet Competing demand
Crew Transport	Crew Transfer Vessels (CTVs)	Commoditised asset	🟢	🟠	🟢 Commoditised Low barrier, easy to scale
Survey and Support	Survey vessels (SV) and patrol boats (PB)	At least 20 survey vessels in Europe *Example companies: Boskalis, Fugro* Patrol boats tend to be a commodity and easily found through brokers *Example companies: Damen*	🟠	🟠	🟢 Sufficient fleet Supply expected to scale with market
Installation: Heavy Lift	HLVs for substations, jackets and topsides	105 worldwide, 17 in Europe *Example companies: Heerema, Saipem, Boskalis, Seaway 7, Subsea7, Technip, DEME, Allseas, other 89 vessels worldwide*	🔴	🟢	🟠 Large fleet available Growing demand, high barrier
Installation; WTG	Jack-up Vessel for quayside turbine installation	19 in the global market. More currently being developed and built for larger turbine sizes *Example companies: Seajacks (5), DEME (4), Windcarrier (4), Boskalis, Van Oord, Jan de Nul, Fred. Olsen, Swire, Seaway 7*	🔴	🟠	🟠 Fleet growing but still limited High barrier to invest

Note: Assessment of available fleet based on RHDHV in-house vessel list and expertise on operational offshore fleet and new-build vessels and verification by online source on fleet investments

7 Supporting supply chain: Vessels

A gap in availability for vessels during peak-installation years is expected. Creation of an attractive market, port accessibility, service and industry clusters will ensure UK vessel supply

Vessel market assessment

Existing vessels, available technology

- The vessel spread required to install floating is existing technology with assets available in the market. Most offshore construction, support and transport assets are available in the market and can be brokered.
- Vessels in the more general service segments, servicing ports, shipping companies and offshore O&G, are in abundantly available. Global supply for these vessels is expected to develop on the back of growing and scaling demand from the offshore wind market.

Competition fixed bottom and O&G

- FLOW is less reliant on specialised vessels than fixed bottom offshore wind but is expected to compete for demand in the more general support segments and with specialised vessels in peak installation demand.
- Heavy lift, cable-laying, and specialist anchor handling tugs with the right capabilities to install future sizes of FLOW turbines need to be built and developed in the upcoming years.
- Fixed bottom demand growth drives current new-build plans which can benefit the use for FLOW.

Scarcity specialist vessels 2025-2035

- Specialist vessels with the right capacity and dimensions are expected to be scarce in the market towards 2030 – 2035. Major transport, maritime and offshore construction firms are gearing up to offer services to the booming offshore wind industry.
- As the sector grows and develops, bespoke vessel designs are being produced and offered on the market. Companies are also actively forming partnerships and sharing assets to be able to quickly respond to global demand.

Peak demand challenge

- Peak demand in deployment and installation levels above the installation supply is expected to lead to vessel supply issues. Due to a combination of high FLOW demand in combination with demand from other sectors a supply gap will emerge.
- There will be mounting pressure to bring additional offshore windfarm capacity online sooner.

Global shipbuilding and supply

- Vessels are built and supplied in a global private market, dominated by Asia-Pacific shipbuilding and demand driven regional presence. Attractiveness and sufficient market demand will draw supply to and presence in the region (e.g. NW-Europe).
- The UK FLOW vessel demand needs to compete in a global market, with limited influence on capacity and shipbuilding options.
- The fixed bottom market might be more attractive for contractors to deploy their assets rather than the FLOW market due to more established market, pricing and expected peak demand in 2025-2030.

Timing of new built vessels

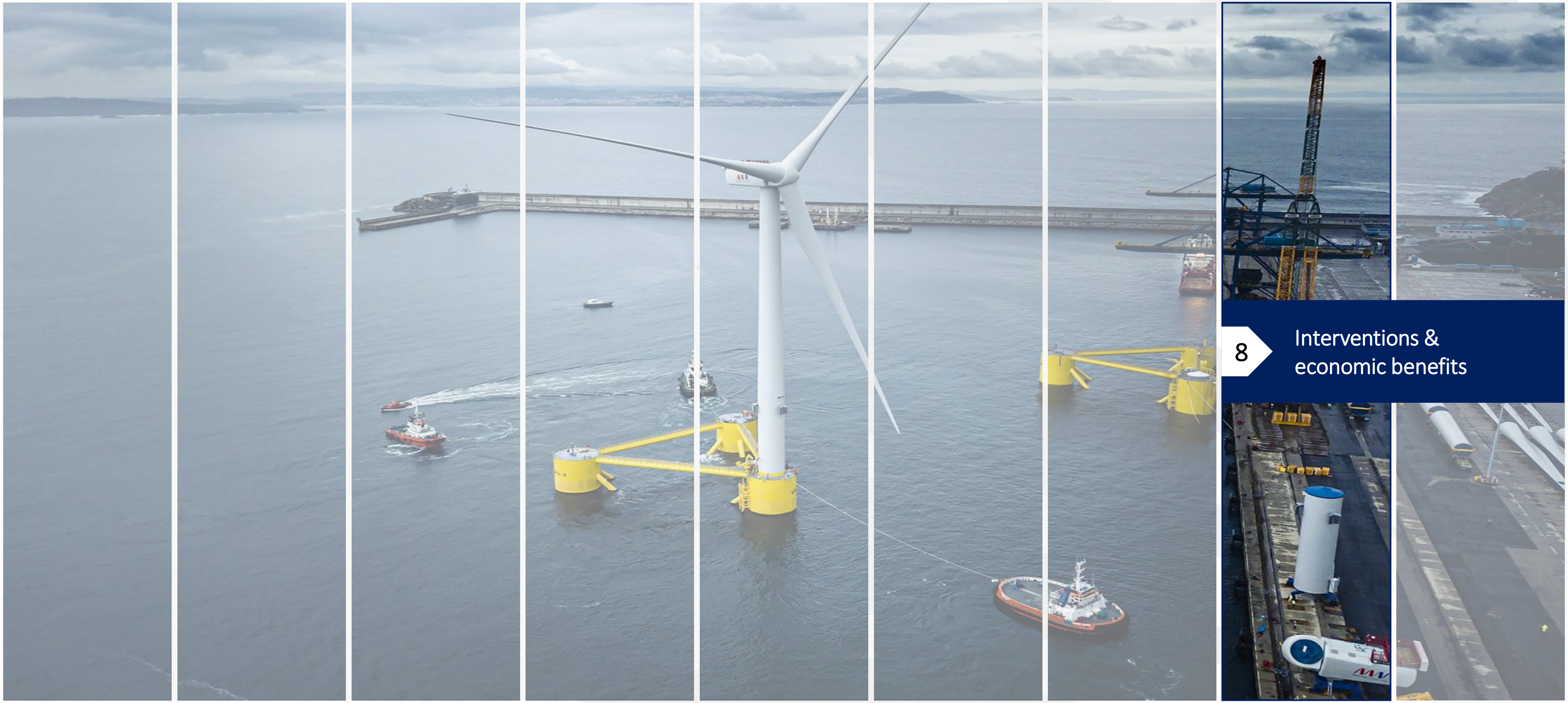
- It is doubtful if the timing of the UK FLOW deployment is in line with the timing of new-built additions to the market.
- New generation vessels are being built based on fixed bottom offshore wind and are to be delivered in the upcoming year. This would improve availability, but shipbuilding of new specialist assets take about 3-5 years (design, FID 1-2 years, building period 2-3 years) which need to materialise in the upcoming years to be in time for FLOW scale up in the UK.

Conclusions & recommendations

- A gap in capabilities is unlikelyy, however, gap in sufficient availability in the market during peak-installation years is probable, especially as both fixed bottom and floating wind will experience high activity levels between 2025-2035.
- Additionally, offshore O&G construction and port operations will compete for demand of partially similar vessels.
- With the limited amount of vessels being owned and operated by UK companies, and the relative strength of European main contracting companies, additional UK investment is low and is expected to remain low in the near future. The opportunity for British firms is likely to remain limited to smaller or support installation work.

Factors that can facilitate an attractive UK-based construction market for FLOW vessels:

1. Creating an accessible market with strong, stable and predictable demand.
2. Ensuring port accessibility for large vessels in line with scaling of the industry.
3. Development of FLOW clusters and bases for vessel operators (e.g. using Freeport benefits).
4. Support frontrunner companies originating from or willing to establish in the UK.
5. Look into potential small specialised shipbuilding collaborations for FLOW.



8 Interventions & economic benefits

Image source: GWEC

We have identified interventions to develop UK FLOW port capacity towards 2040, which will require significant adjustment and expansion in port infrastructure

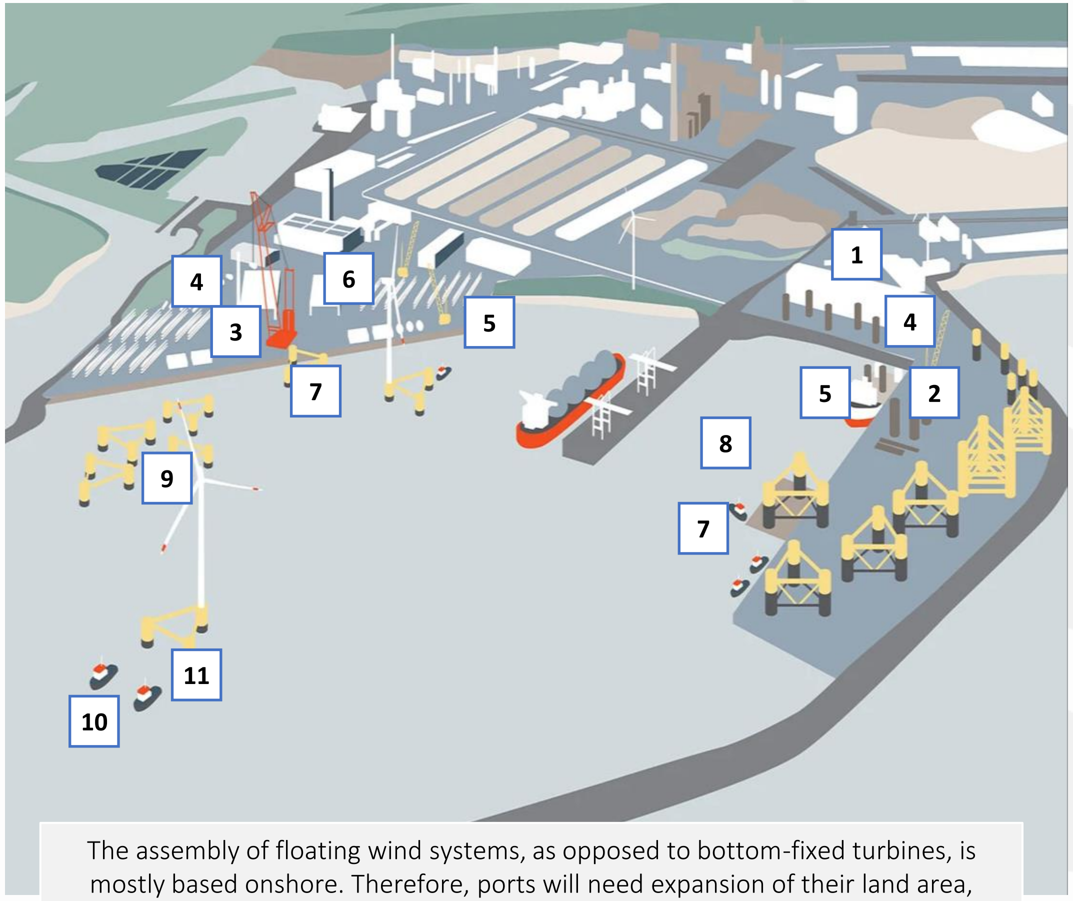
Identified interventions

Required port capacity

Scotland 2030 – 2040:
Industrialised scale:
3-5 Integration Ports

Celtic Sea 2030 – 2040:
Industrialised scale
2 Integration Ports

Nationally 2030 – 2040:
Industrialised scale
4-6 manufacturing / assembly ports



The assembly of floating wind systems, as opposed to bottom-fixed turbines, is mostly based onshore. Therefore, ports will need expansion of their land area, quay reinforcement, storage for components, carrying capacity, cranes and other retrofits to host mass production of substructures and other turbine components.

Intervention	No.
Manufacturing and fabrication Concrete manufacturing and steel assembly facilities	1
Assembly lines and pads Steel and concrete substructure assembly lines	2
Integration area Construction and preparation of new or repurposed land	3
Laydown-storage area Construction of new, reclaimed or repurposed land	4
Quayside New quayside or lengthen and strengthen existing	5
Cranes & equipment Installation of ringer cranes, SPMT, rail systems and other equipment	6
Harbour area Widening and deepening berth pocket and harbour area	7
Launch facilities Build facility, purchase launch equipment and lift systems	8
Wet storage Identification and installation of mooring systems	9
Access channel Widening & deepening	10
Installation fleet Availability of installation and support vessels	11

Image source: COWI

The identified port interventions have been quantified by establishing detailed development, investment and operational expenditure levels based on RHDHV expertise, confirmed by port stakeholders

Intervention cost

A high-level estimate of port investment to establish industrialised scale integration and manufacturing/assessment facilities has been developed based on port infrastructure requirements and cost data from national and international maritime projects held by Royal HaskoningDHV.

The purpose of this estimate is to provide a typical investment level that will be utilised as a basis for determining economic benefits.

It is noted that every potential development site will have its own unique challenges, particularly relating to dredging and reclamation, that will result in a wide range of investment requirements.

In order to provide a typical investment level for each port type, the dredging and reclamation requirements associated with a number of potential port locations have been determined whilst the average requirements for dredging and reclamation have been incorporated into the port investment estimate.

DEVEX

Development costs up to start of port infrastructure construction, including:

- Project costs
- Consenting and approvals (including environmental and compensatory habitat)
- Investigations and surveys (landside and overwater geotechnical investigations, metocean, bathymetric)
- Design development and contracting

CAPEX

Supply and installation costs for port infrastructure, including:

- Marine civils infrastructure (dredging, reclamation, quay wall construction)
- Landside civils infrastructure (heavy load areas, surfacing, monitoring & evaluation, drainage)
- Operational facilities and equipment (concrete batching and slipforming facilities, SPMTs, craneage, load-out barge, rail system)

OPEX

Ongoing costs associated with port infrastructure operations, including:

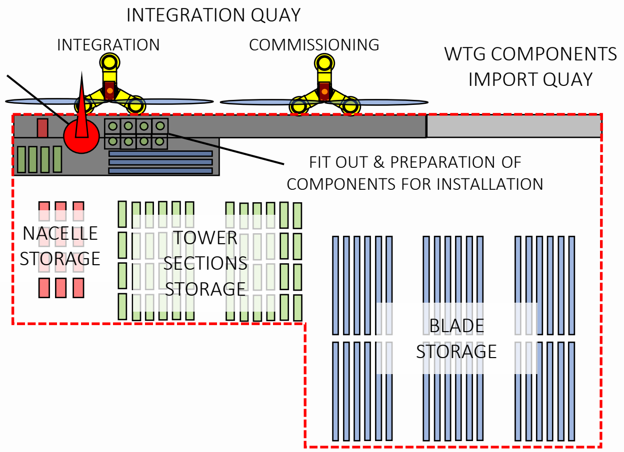
- Maintenance dredging
- Maintenance and repair of infrastructure (quay walls, paving, utilities)
- Leasing of ringer crane
- Noted that energy and labour cost are assumed to be included in the developers costs

The port intervention cost estimations have resulted in a port investment envelope between £3 to 4 bn to adequately develop FLOW port infrastructure in line with ambitions over time towards 2040.

Port investment estimation

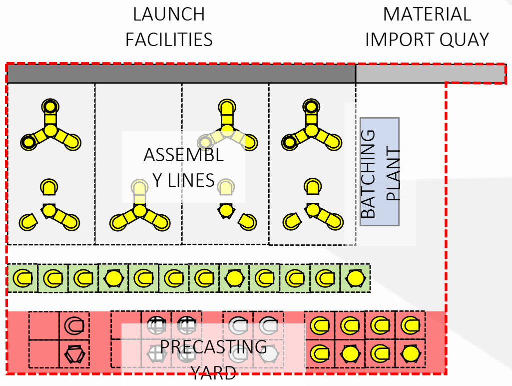
Integration port

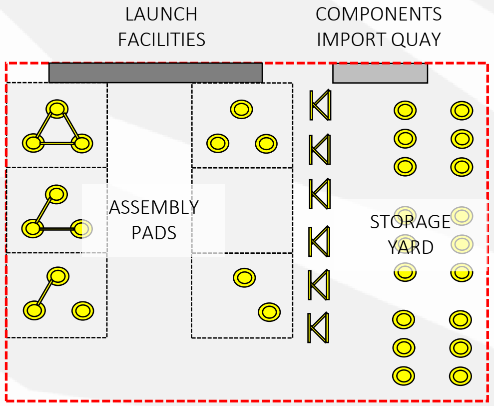
ITEM	INVESTMENT (17MW)	INVESTMENT (20MW)
Marine civils	£80-220mn	£90-240mn
Landside civils	£30-60mn	£30-80mn
Equipment (incl. cranes)	£10-20mn	£10-120mn
Total CAPEX (Capital Expenditure)	**£150-350mn**	
Total DEVEX (Development Expenditure)	**£10-50mn**	
Total OPEX (Operational Expenditure)[1]	**£20-30mn**	



Concrete manufacturing & Steel assembly ports

ITEM	INVESTMENT (17MW)	INVESTMENT (20MW)
Marine civils	£50-120mn	£70-170mn
Landside civils	£110-300mn	£130-360mn
Equipment (incl. cranes)	£30-50Mmn	£30-50mn
Total CAPEX (Capital Expenditure)	**£250-600mn**	
Total DEVEX (Development Expenditure)	**£20-80mn**	
Total OPEX (Operational Expenditure)	**£5-10mn**	





Total estimated investment level[2]

Scotland 2030 – 2040
Industrialised scale
3-5 Integration Ports
£750mn-1.250bn

Celtic Sea 2030 – 2040
Industrialised scale
2 Integration Ports
£500mn

Nationally 2030 – 2040
Industrialised scale
2-3 Concrete Manufacturing Ports / 2-3 Steel Assembly Ports
£1.7bn-2.6bn

Total FLOW port investment envelope 2040

£3-4bn

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1) Including ringer crane leasing cost, not included in CAPEX
2) Average of the identified CAPEX ranges times the amount of ports

The benefits of the investment in port infrastructure are significantly greater than the costs. The UK will generate £3-4 of GVA for every £1 it invests in port facilities to support the FLOW ambitions.

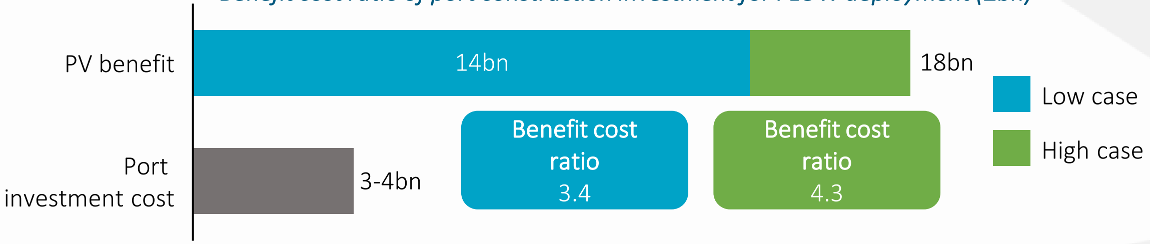
Required investment

- Delivering industrialised scale FLOW in the UK will require significant and timely investment in port infrastructure adjustments and expansion.
- The FLOW TF have estimated that the initial investment required **to develop the 5-7 integration ports and 4-6 substructure manufacturing/assembly needed to underpin industrialised scale FLOW deployment in the 2030s will require between £3-4bn (ratio of 3.4:1 and 4.3:1).**

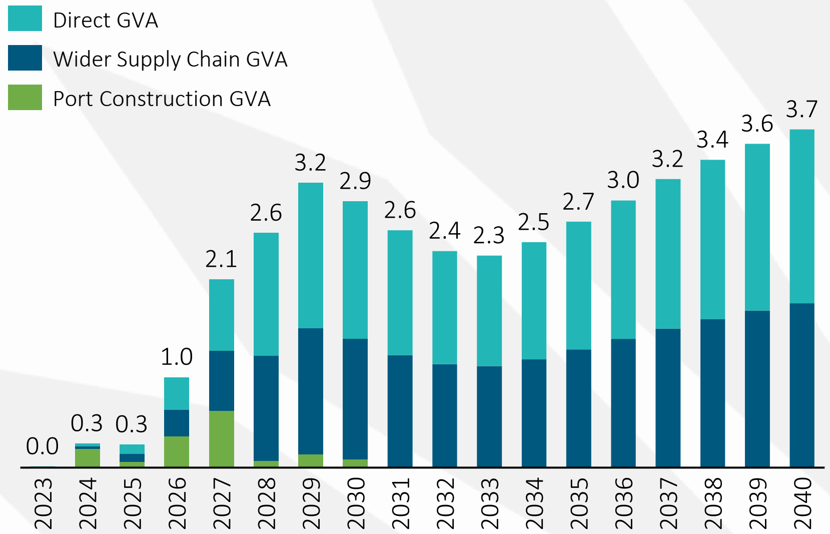
Economic benefits

- The interventions identified in this roadmap will accelerate port development and remove likely bottlenecks to enable the aspired scenario of 5GW deployment in 2030 and 34GW in 2040. Once realised, this will generate major economic and social value in the UK.
- To calculate the economic benefits arising from port investments towards 2040, this report has estimated the Gross Value Added (GVA) and job creation potential from both port investments and the expected acceleration of FLOW deployment these investments will bring.
- Delivering on the modelled aspired high case scenario will result in a **total expenditure of £56bn by 2040**, which is equivalent to £1.7bn for every GW of FLOW.
- Over the BaU scenario (i.e. no intervention), implementing the recommendations required to achieve the high case scenario will generate **£26.6bn additional GVA in the UK. The present value of this future sum is 18bn.**
- **Simply put for every £1 invested in port facilities to support the FLOW sector the UK would generate approximately £3.4 to £4.3 of added value to the economy.**

Benefit cost ratio of port construction investment for FLOW deployment (£bn)



Annual GVA impact towards 2040 based on the aspired high case scenario (GVA in £bn)



Aspired high case scenario GVA results	£bn
Total expected expenditure	56.0
High case scenario GVA	40.2
High case scenario increase over BaU scenario	26.6

The approach in short:

- To make an estimation of the economic benefits generated by UK port development, the FLOW TF have combined our "aspired high case" deployment and technology scenario with the estimated cost and required port capacity towards 2040.
- The estimated DEVEX, CAPEX and OPEX levels have been spread over the timeline based on the assumed port development timing and have been adjusted for learning rates[1] (to reflect expected decreasing cost and learning curve in the FLOW sector over time).
- We have also made an estimation of FLOW and port construction UK content levels, which have been translated into GVA figures based on ONS and UK Economic Multipliers. This used the UK Greenbook discount factor of 3.5% and all prices in real prices to calculate the NPV.
- This analysis does not consider additional value and synergies with existing activities in fixed bottom offshore wind or with overseas offshore wind opportunities, which would increase the figures further.

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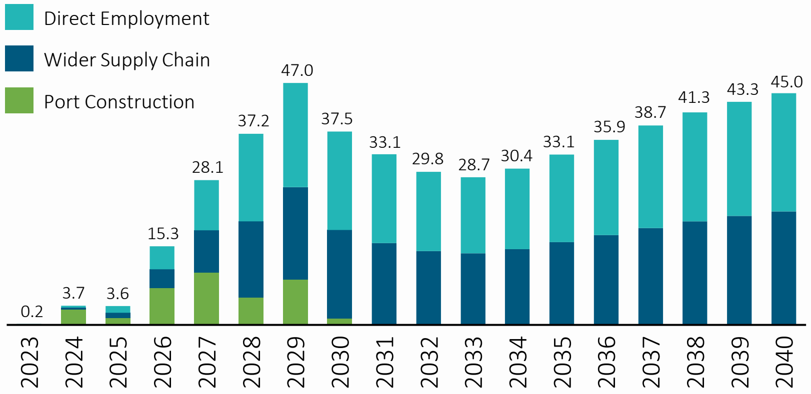
1) Based on ORE Catapult Cost Reduction Pathway Model (December 2020), verified by recent research figures from DNV Energy Transition Outlook 2022 and Floating Offshore Wind: The upcoming five years

The aspired high case scenario is expected to generate 23,000-30,000 jobs. Availability of workforce could become a bottleneck and should be further identified in a skills and workforce development programme

Skills & workforce development

- In line with the aspired high case scenario, **employment in FLOW is expected to peak in 2029 at 47,000 jobs across the UK**, including around 8,000 jobs in port construction. **On average, port construction will support around 5,300 jobs per year between 2025-2030**.
- Employment will grow steadily in the 2030s as the level of annual deployment increases and there is greater demand for O&M activities to service the growing installed capacity. **By 2040, the FLOW sector will support a total of 45,000 jobs across the UK, with about 35% representing employment in FLOW operation.**
- The majority of the employment in the FLOW sector will be linked to the development and construction of the projects, supporting the 2 to 3 GW of FLOW that will be built each year between 2030 - 2040. The main opportunities are associated with the construction of the floating substructures.
- **When compared with the BaU scenario, the additional jobs created by implementing the recommendations from this roadmap ranges between 23,000 to 30,000.**
- As job creation is pushed by our ambitious scenario and early-stage port construction, this spike and job development over time is not related to the sustainability of the employment created. It does, however, highlight the incredible task we have on our hand in terms of skills to service the 5GW by 2030 target.

Total annual job creation towards 2040 based on the aspired high case scenario (number of jobs x1,000)



Job creation (x1,000)	Aspired high case	Low case
High case scenario increase over BaU Scenario	29.8	23.5
Average annual port construction-related jobs	5.3	5.3

Industrialised scale FLOW as well as the build up and operationalisation of port infrastructure will require a significant workforce with multiple new trades related to FLOW manufacturing, assembly, logistics, integration activities being needed. This creates opportunities for new employment and the transfer of existing skills into a low carbon industry. Research from *ORE Catapult* [1] identifies key shortfalls in skills and jobs which also highlights barriers for the transition of marine operations and maintenance activities.

Challenges from centralising skills

- The UK has a strong track record in quayside turbine tower assembly, general marshalling and offshore assembly and integration. It is also well established in both the development and operational stage of offshore projects. These skills and workforce activities can be expanded over time and dispersed based on project needs and port developments in line with sector growth. Partially this demand will be filled up by attracting similar expertise from other sectors to FLOW (O&G, fixed-bottom, or other port operations).
- **The expected size and scale of FLOW activities will however create challenges in attracting skills, especially when these activities are centralised in larger hubs**. Capacity issues could also arise in specific regions close to projects or expanding FLOW ports with limited capacity to service the overall skills required.

Expected skill constraint

- **FLOW and port workforce constraints are expected**, particularly in electrical (cable); mechanical and data engineering; project management for major projects; crane operators; Health, Safety Environment and Quality officer; senior and skilled construction personnel; and, marine and subsea expertise.[1]
- **Concrete manufacturing:** There is a lower skills threshold in the UK with more opportunity for workforce to move from existing buildings and civils construction industry. It will require training of personnel to move from the conventional concrete manufacturing activities to new specialised FLOW manufacturing.
- **Steel fabrication:** When developing steel fabrication facilities is considered, skills around welding, steel fixings, high degree of automation and more advanced manufacturers would then be needed.
- Clarity on the selection of concrete or steel will help the industry to decide the level of training and workforce needed. **Generally, there is a lead time of at least 3 years to train personnel and upskill existing employees, while influencing educational choices early stage would take much longer to come into effect.**
- Relevant joint actions, between industry, developers, governments and education offices, could consist of the creation of training centres, dedicated education and retrain programmes. **Identification of the required workforce and skills should be fitted into a FLOW skills and workforce programme.**

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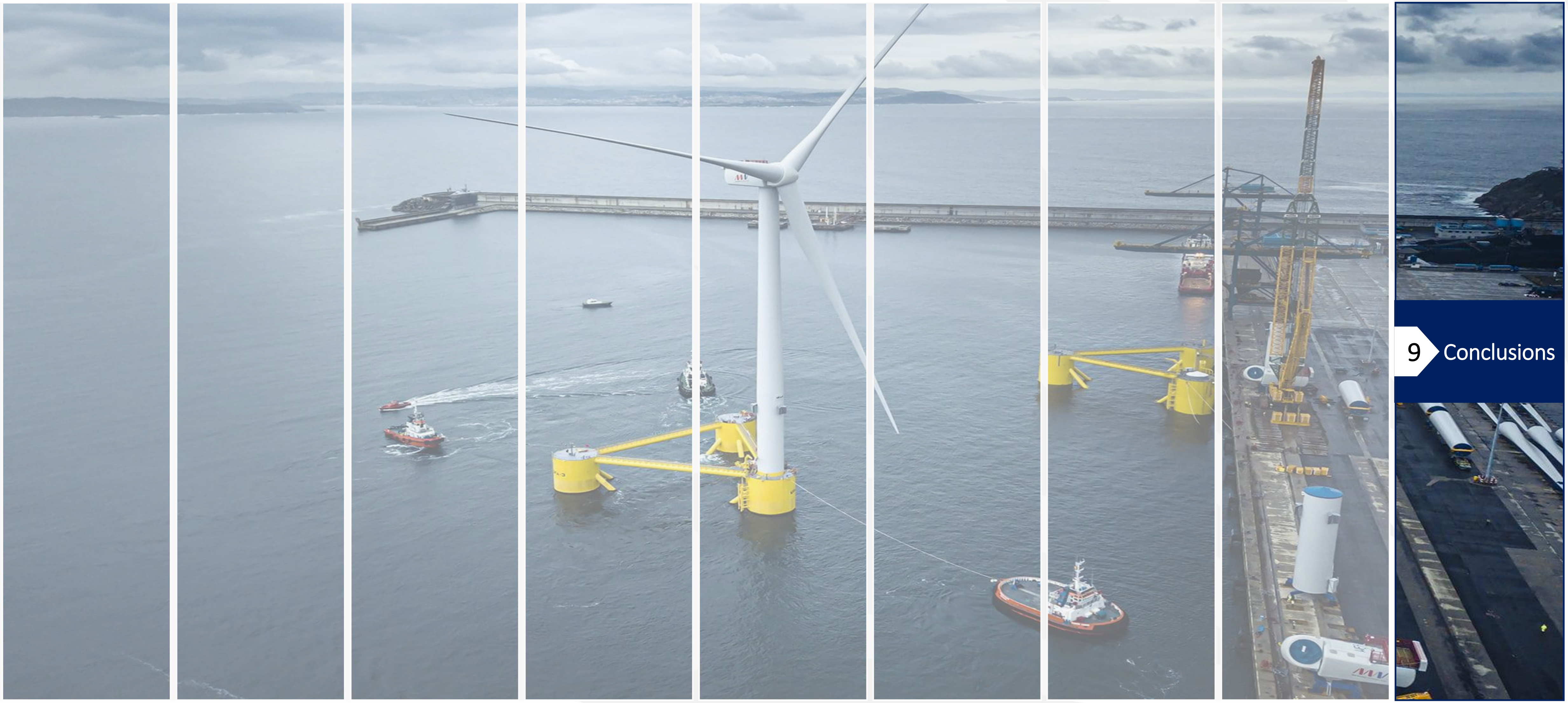
1) ORE Catapult, FOW CoE: Risks to Project Development – People, Skills and Vocations



9 Conclusions

Image source: GWEC

Substantial investments must be mobilised to assure port infrastructure is ready by 2028-29 to deliver UK FLOW ambitions; industry needs to collaborate to create certainty on requirements and design envelopes

Conclusions

① There are currently **no port facilities identified regionally or nationally that fulfil the infrastructure requirements for an industrialised scale integration**, substructure assembly or manufacturing facility. Approximately **fifteen port locations** have been assessed which, with varying degrees of investment, could be developed to provide industrialised scale integration, assembly and manufacturing facilities to support FLOW deployment in the UK. Potentially there are more ports that could develop towards the identified requirements, while there is also a significant opportunity and need for port capacity development related to cables, turbine components, mooring and anchors, and O&M.

② Our assessment shows that when considering the deployment scenarios and the FLOW technology assumptions, the projects in **Scottish waters require 2-5 integration ports while the Celtic Sea requires 2 integration ports**. In addition, at least **4 ports are required to service steel assembly and concrete manufacturing for FLOW;** with the configuration of these ports being dependent on the direction of preferences for substructure technology.

③ **Timely investment in port infrastructure development is required to ensure ports are fully prepared by 2028-2029 to support industrialised scale deployment of FLOW in the 2030s**. The timeline towards 2030 is tight and it seems challenging to deliver on our ambition if prompt action is not taken, and port planning and consenting uncertainties are not minimised.

④ Required port infrastructure action should **focus on imminent action to deliver on the pre-2030 opportunity by adjusting port facilities**, while preparing for industrial scale deployment and determining the **common basic infrastructure designs** for the integration and manufacturing/assembly ports as identified in this port assessment.

⑤ **The development of concrete and steel manufacturing facilities in the UK combined with a targeted proactive approach towards localisation of turbine, cable, tower and mooring manufacturing should be a key spearhead of FLOW industry development.** This will increase certainty and efficiency in the FLOW supply chain and also attract the required vessel capacity for UK FLOW projects.

⑥ The UK has a vast potential in FLOW which will bring economic value, industry activity and the creation of thousands of high skill jobs. **A better understanding of what facilities need to look like and how they should work collaboratively will help the industry maximise the wider benefits these opportunities will bring.**

⑦ **Clarity and alignment on requirements and design envelopes could give a boost to required developments and help to screen the suitability of ports and their potential for FLOW.** The development of a universal design approach that fits the majority of foundation types, for example: developing layouts; launch designs; wet storage requirements; and an in-depth study on manufacturing and assembly process requirements for both steel and concrete.

⑧ Common industry practices and design requirements could be jointly established to allow appropriate port infrastructure to be developed and optimised more effectively. In order to be able to offer a collective opportunity for ports, **collaboration between multiple developers and ports needs to be explicitly championed by the UK government**. Finding a solution to this will allow for joint infrastructure developments, a better definition of design requirements and a more deliverable multi-port strategy that avoids interfering with developers' commercial interest and technical direction preferences.

Uncertainty in port requirements, technology, projects, funding and required skills currently hamper FLOW port developments and business cases

What are the challenges?

Port requirement limitations

The key limitations of existing port infrastructure are generally based around the potential width and depth of the floating substructures.

Increased widths/depth are required in access channels and at berths, and there is limited availability of suitable landside area in the majority of ports at this present time.

Uncertainty in and lack of standard technology and requirements

Differences in FLOW solutions, processes and required dimensions coming from developers and market expectations are a challenge for ports facing the mentioned requirement limitations.

Nevertheless, **broad similarities between technology-specific port requirements are identified and must be further detailed to cater for timely and common port infrastructure needs.**

Project-by-project approach towards port facilities

Port authorities and FLOW developers are currently securing, procuring and developing supply chains on a project-by-project commercial basis. This leads to an imbalance in requirements demanded from developers and available port capacity.

A project-by-project approach ignores optimal multiple port-project combinations and hampers scaling of infrastructure and development of holistic business cases.

Uncertainty in market and project developments

There is uncertainty in the timing, scale and requirements in the market which makes it difficult to plan port needs. This is driven by high uncertainty in project execution timing, attrition, project technology developments and a lack of early-stage binding commitments.

This in combination with the fluctuating nature of the project-based use of port capacity is making it **difficult to plan infrastructure development.**

Technology providers, ports and developers are increasingly developing concepts together, most often on a project basis but industry collaborations are emerging.

Developing business cases and unlocking investments

The cycle of port investments not coming off the ground in time due to a developer not being able to make binding commitments before CfD agreements are in place needs to be broken. **The development of port infrastructure dedicated to FLOW infrastructure is currently limited by a lack of a viable business case, high investments cost, available funds and more attractive alternative investment options.**

Getting port investments off the ground is key, with FLOWMIS being a first important step, but additional funding from national infrastructure funds and public private partnerships will be requirement for the long-term infrastructure development need.

Availability of workforce and skills[1]

Industrialised scale FLOW will **require a significant increase in the skilled workforce with multiple new trades related to FLOW manufacturing, assembly, logistics, integration activities being needed.**

This creates opportunities for new employment and the transfer of existing skills into a low carbon industry. Numerous challenges are expected however, and key shortfalls in skills and jobs have been identified in the ORE Catapult Report[1] which also highlights the barriers for the transition of marine operations and maintenance activities.

Note: 1) ORE Catapult has done extensive work on this topic: https://ore.catapult.org.uk/?orecatapultreports=FLOW-coe-risks-to-project-development-people-skills-and-vocations

FLOW Port infrastructure requires industry collaboration for strategic planning to develop infrastructure requirements, common build strategies, investment approaches and supply chain activities

Recommendations

In order to develop and scale port infrastructure in time to facilitate the FLOW ambition of up to 5GW by 2030 with a view to this report's modelled deployment of 34GW by 2040: A collaborative programme needs to be taken forward in the UK to jointly develop FLOW port infrastructure. We advise that this should contain and detail the following interventions, investments and investigations:

Port planning recommendations

Progress a joint industry programme for a UK multi-port strategy and regional cluster development

Developing UK port facilities is critical to accelerate the deployment of FLOW and maximise the socio-economic opportunities. **A joint industry programme should support multi-port use and regional clusters of ports for the pre-2030 deployment ambition, with the aim of developing long-term specialist ports**. This multi-port strategy must be supported by a value proposition towards ports, developers, government and key stakeholders which emphasizes the commercial opportunities, synergies for ports and the wider economic gains. There is a need for ports to collaborate and distribute activities themselves to avoid inefficiencies.

Developing larger hubs might sound attractive in terms of efficiency, scale and focus, but there is no evidence preferring the development of large hubs looking at fixed bottom offshore wind.

Furthermore, due to the diversity in the FLOW value chain and the expected demand coming from large scale FLOW deployment and overseas opportunities, the UK needs to rely on a broad range of ports playing their role in the success of FLOW.

Develop smart port infrastructure for 5 -7 integration ports and 4 manufacturing/assembly ports in the UK

The initial port infrastructure focus should be on developing basic and smart port infrastructure for up to 5 integration ports in Scottish waters and 2 integration ports for the Celtic Sea. Two concrete manufacturing ports and two steel assembly ports are required to support the aspired FLOW ambition.

This can be based on the common and no-regret must have requirements as well as agnostic technology and concepts. The export opportunities and synergies with fixed-bottom offshore wind should be considered when developing these port facilities.

Port projects should commence before the end of 2023. 4 to 5 years is an agreed time for port development but **port planning and consenting might differ per type of port / facility which could seriously hamper progress and potential port sites** . Mechanisms to standardise, smoothen or speed up consenting would be important to reduce the bottleneck/risk of ports not being able to support first projects.

Construct a minimum threshold of 'must-have' FLOW port infrastructure

The 'must-have' port infrastructure projects need to be developed to provide the **minimum threshold of facilities without overinvesting on peak demand.** This will service initial deployment and **assure sufficient port capacity for the market to meet the anticipated deployment.** It will provide confidence in what ports are able to handle which can positively influence other business cases. The smoothening of deployment will also provide a basis to gradually expand if the market is scaling.

Early stage cross-industry development of port requirements and design envelopes is key to success.

To avoid new FLOW facilities becoming obsolete, FLOW port infrastructure needs to be planned and developed to accommodate future advancements of FLOW. **Progressing joint development of port design envelopes determined by agreed technology development directions and standardisation is essential in creating build for purpose infrastructure.** Different developer procurement strategies and port commercial interests need to be taken into account when finding commonality.

Execute a national wet storage requirement study

Given the size of FLOW units and the high rates of deployment, it is recommended that an **additional national study into wet storage requirements** be carried out. This would look to identify the particular requirements for each technology, scale of the issue and the identification of potential sites.

Develop and leverage cross-industry collaboration and working groups

A structured collaboration between groups of FLOW developers and port owners would allow the multi-port strategy to focus on their common interest to jointly identify, develop and share port infrastructure facilities. Not only for FLOW but also to support wider port efficiency and other markets. This will help mobilise and bundle private and public funding in a strategic investment approach to get projects off the ground. Existing initiatives by OWAT, OWEC, SOWEC, ORE Catapult, can be used and empowered to support structure cross-industry collaboration.

A joint proactive approach towards attracting and developing critical and valuable FLOW supply chain activities to the UK are an important part of the success of FLOW in the UK

Supply chain development recommendations

Develop FLOW substructure manufacturing and assembly facilities in the UK

The UK FLOW ambitions would benefit most from the development of facilities for FLOW substructures. Early development in this segment would accelerate deployment, create a strategic advantage to set industry and production standards, develop technology agnostic steel and concrete concepts, secure supply for UK ports and projects, improve efficiency and price certainty in the value chain, while potentially creating export opportunities for both the industry and ports.

The feasibility and attractiveness of concrete substructure should be further investigated

Further investigation in the feasibility, attractiveness and UK benefits of developing concrete substructures as a viable solution for FLOW. To get more clarity on the concrete manufacturing port feasibility and infrastructure requirements, the UK's potential for concrete construction needs to be better understood.

At first glance, it is expected that lower investment will be required due to the UK's existing industrial base for concrete solutions in other sectors. Additionally, it will also unburden steel supply and associated skill requirements as there will be healthier balance between the use of steel and concrete in the UK market. The question remains if concrete is going to be a widely used as the accepted solution to condone further development of infrastructure and skills.

Investigate the feasibility of modular and standard based steel substructure fabrication in the UK

UK steel substructure fabrication facilities are required to service and secure UK deployment ambitions, but can only be developed on the back of highly modular and based on standard components. Standardisation of steel structural components (e.g., tubes) by designers across the industry would greatly assist the industrialisation of the fabrication industry in UK.

Multiple steel fabrication locations will be required in the UK to supply FLOW steel assembly ports; these can feed into one or more assembly location. Considering the increase in demand from FLOW, the UK would need to bridge the gap with existing European assembly capacity.

British ports and fabricators are unlikely to be able to compete with suppliers in the Far or Middle East in terms of infrastructure scale and labour cost, but with the high cost of transport their might be a case for securing supply, speciality fabrication and the value added via indigenous strengths in areas such as modern high-end automated welding must be prioritised.

Develop an attractive and accessible market for key technology and vessel owners.

The attractiveness and efficiency in the UK market will improve project execution and can increase the willingness of developers, contractors and vessel providers to select a country as home market for offshore wind activities. **As there is limited grip on securing vessels in a global market, the creation of an established markets will be more attractive for contractors to deploy their assets as there is a market supply-demand dynamic, pricing and a lower technology risk.** Adequate supply chains, dedicated port infrastructure, optimised logistic processes and availability of vessel berthing and maintenance options all contribute to the attractiveness for vessel owners for market selection.

The UK government and the FLOW industry should work together to develop a proactive approach to attract strategic supply chain activities

Supply chain activities related to turbine, mooring, cable manufacturing, tower fabrication will improve the UK supply chain, and are critical to FLOW success and generate efficiency, economic value as well as supply security for UK FLOW projects.

Healthy demand, progression and predictability of FLOW projects, utilising Freeports to attract industry investments and creation of FLOW clusters will improve attractiveness to localise. The introduction of non-price based criteria within leasing rounds that focus on building up local supply chains could be identified to priorities early stage development and improve port business cases.

FLOW port innovation programme

Part of the UK's technology, innovation and research for FLOW could be more explicitly focused on innovative port infrastructure development. This programme could focus, both on new infrastructure concepts for handling FLOW components, and on process innovations that could reduce port requirements and investments. For example, innovative ways to reduce cranage capacity, advanced launching solutions or the used of floating port structures. The latter have not been considered in this report but could be an alternative to deliver flexible port capacity. Floating quays and pontoons for crane installation could be a solution to enlarge infrastructure in constrained areas where temporary expansions could deal with the cyclical demand in FLOW. It could possibly reduce investments and would make it easier to relocate assets. Further research and development of innovative solutions would be worthwhile, given the particularly unique set of requirements for FLOW development.

Port developments will benefit from structural investment support and clarity on the UK project pipeline, overseas opportunities, the skills and workforce gap as well as insights on supply chain emissions

FLOW sector support and development recommendations

Clarity of pipeline and smoother deployment rates for the development of FLOW.

Planned visibility over long term deployment of floating offshore wind is vital to identify required port utilisation. The pipeline of FLOW developments should be managed to avoid multiple projects competing on similar deployment windows which are at risk of bottlenecks. This could be by reducing incentives for developers to be first, taking a more directive role in deployment timing by establishing a revised phasing policy for FLOW as part of the CfD revision or similar to recent CCS phasing concepts, or having a more staged approach for grid connections and allowing for direct interconnector connections.

More clarity on the credibility of deployment scenarios and project pipeline certainty and timing is essential, and could be improved by centralised staging of projects. The prioritisation of deployment as quickly as possible will lead to lower development costs. Developers will be forced to seek solutions available at that time. Delays to projects due to ports not being ready to provide services will risk developers having to seek support elsewhere which could hamper FLOW deployment ambitions.

Urgency and continuity of government investment support

A continuous or recurring financial support scheme should be in place with a mission driven investments focus and the aim of securing both public and private funding. Investment support could focus on unlocking public infrastructure development bank funds, connecting (regional) public-private investments, linking transport infrastructure investments by considering network effects, and by assuring revenue streams over time.

A sense of urgency and identifying the right sequence over time is essential, which also includes ongoing and evolving investments rather than one-off large investments at the beginning. Lessons learned from FLOWMIS need to inform the next stages of financial support. In developing support instruments, the UK government should consider support schemes in the EU and other offshore wind focused countries, to assure adequate support and considering the competitive position of the UK. One example is the recent state aid measure from the French government, approved by the European Commission[1], to support a FLOW project.

Financial support from the government should not focus purely on the obvious port solutions. As business cases for key ports will improve, attention is needed on less viable sites that are ultimately needed to solve future bottlenecks. Based on the expected requirement, port infrastructure needs to be developed beyond the obvious well-suited locations, as there will also be a significant requirement for port capacity in other areas (cables, turbine components, mooring, anchors, O&M).

Research UK export opportunities and competing demand

As the main focus of this research was on UK port infrastructure for UK FLOW ambitions, **further research is required to assess the export potential of FLOW activities and related port services overseas**. Export opportunities will likely arise in the North Sea, particularly from Norway and France, and in the emergence of new offshore wind markets in Europe, Asia and North America.

Identifying export opportunities should also focus on generating insights on competing demand from those countries and from other sectors (potentially) using similar technology. This would improve the development of holistic business cases for port infrastructure, as the returns can be based on both UK and domestic FLOW activities and additional business activities.

Identify the expected skills and workforce gap as a starting point for a development programme

Early identification of the required workforce and skills to develop, scale and operate port infrastructure with a supportive supply chain, **is essential to develop a skills and workforce programme.**

The GVA analysis shows that the UK benefits in terms of economic value and job creation. However, scarcity of skills and workforce should be identified and addressed early on due to a lead time of about 3 years to train personnel and upskill existing employees.

Develop insights in supply chain & port emissions

There is limited knowledge of the embedded emissions associated with the FLOW supply chain and the environmental impact of attracting manufacturing, assembly and integration to the UK. The same is true for the difference in emissions of FLOW port technology and operations.

The net zero benefits of nurturing a home-grown FLOW port industry could however potentially be undermined if the environmental impact of developing it are not considered in its development. Nonetheless, this could be mitigated by the use of low carbon technologies (e.g. electric crane, e-fuels, hydrogen fabrication etc.); introduction of non-price based criteria for emissions and local supply chain development within leasing rounds and port infrastructure support; and opting for low carbon solutions when building ports.

For the purpose of this research, we have used public available reports, ORE Catapult's dedicated work for the FLOW TF and engaged stakeholders throughout the process

Literature

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FLOW TF Composition

FLOW working group
Everoze / BP
RUK
Mainstream RP
OREC
Department of Energy Security and Net Zero
Cierco Energy
Hexicon
HVM Catapult
CES
Various, including Sheffield Hallam University
Subsea7
Celtic Sea Developers Alliance
NZTC
RWE
Marine Energy Wales
TCE
Industry Wales
DiT
British Ports
Xodus Group
UK Major Ports
LumenEE

FLOW TF Board
COP
Wales Government
Scottish Renewables
CES
OREC
RUK
Scottish Government
Aker
Department of Energy Security and Net Zero
Orsted
Northern Ireland Executive
SSE
TCE
SSE
Mainstream RP
Equinor

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The Crown Estate Scotland, RenewableUK, The Crown Estate, Scottish Renewables

Sources (2/2)

For the purpose of this research we have used public available reports, ORE Catapult's dedicated work for the FLOW TF and engaged stakeholders throughout the process

Supporting deliverables

Deployment scenario

Specifically for this roadmap ORE Catapult has developed a range of deployment scenarios that focus on reaching the FLOW ambitions set out by the UK Government.

They have been prepared to support the discussions for this roadmap on the scale and speed of enabling actions required to facilitate timely, cost effective deployment of floating offshore wind projects in the UK, and the resulting supply chain and infrastructure requirements delivering these may have.

Content

- Background on UK seabed access
- Role of offshore wind and FLOW in delivering net zero
- Current UK targets and ambitions
- Fixed versus floating developments
- Deployment scenario 2030 and 2040-2050 extrapolation
- ScotWind, INTOG, Celtic Sea scenarios and commentary

Technology assumptions

This document contains the technology assumptions related to FLOW technology and fabrication, transport & installation and operations, maintenance and decommissioning process expectations.

These assumptions were specifically composed by RHDHV for this report. They have been established with the FLOW TF and other expert stakeholders in dedicated Technology sessions. They have been used to create adequate and agreed input for the industry requirement formulation and gap analysis.

Content

- Critical technology assumptions
- FLOW production and industry assumptions
- FLOW port requirement assumptions
- FLOW installation, vessel and O&M assumptions

GVA methodology & results

In order to determine the economic benefits of the roadmap, Biggar Economics has calculated the additional GVA-value and job creation impact.

The supporting document contains an explanation on the methodology and model used to calculate the economic value from both the port investments and the FLOW deployment activities.

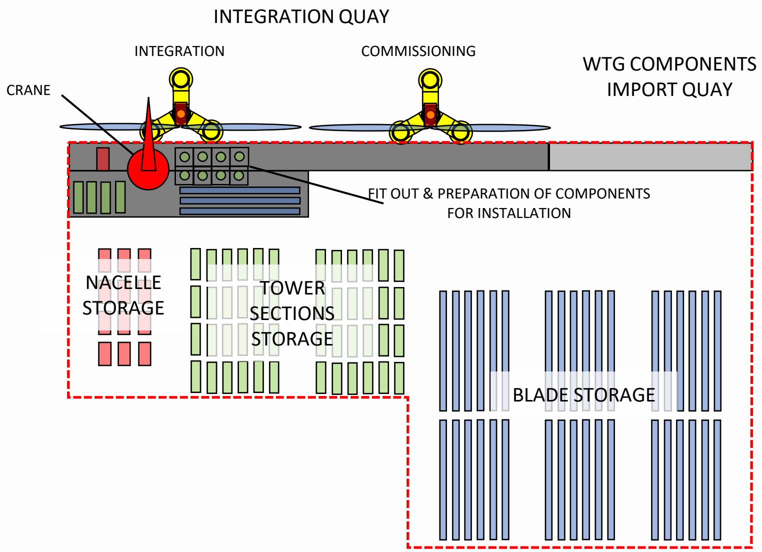
Content

- Economic impact modelling and methodology
- Economic impact of FLOW
- Employment impact of FLOW
- Sensitivity analysis

FLOW TF Industrial Roadmap 2040
Appendix

Port type details (1/3)

Integration port



REQUIREMENT	17MW	20MW
Distance from Wind Farm (km)	265	265
Entrance Width (m)	120	130
Air Draft (m)	Unrestricted	Unrestricted
Access Channel Width (m)	230	260
Access Channel Water Depth (m below MLWS)	15.0	16.5
Landside Area (ha)	20	25
Storage Area Bearing Capacity (t/m2)	10	10
Integration Quay Length (m)	400	440
Integration Berth Water Depth (m below CD)	15.0	16.5
Integration Area Bearing Capacity (t/m2)	20	20

An Integration Port, also referred to as a Staging or Marshalling Port, is a facility used during the construction of the wind farm to install the wind turbine onto the floating substructure prior to deployment to the wind farm site.

An Integration Port is expected to comprise the following facilities:

- Import Quay – import and off-loading of blades, tower section and nacelles from OEMs.
- Storage Yard – buffer storage of components between the import quay and the integration quay to minimise risk of disruption to production
- Integration Quay – area for pre-integration activities on components prior to crane lifts onto the substructures moored adjacent to the quay. Following installation the unit would be moved along the quay to a commissioning area.
- Wet Storage – short-term buffer storage may be required for non-integrated substructures to de-risk the supply chain and for integrated units until the availability of suitable weather windows for towing to the wind farm site.

In determining the port infrastructure requirements for an industrialised scale integration port, the following facility parameters are assumed:

- The deployment of units to the wind farm site is predominantly driven by available weather windows, which have a best accuracy within 72 hours. Based on a tow speed of 3 knots and tow time of 2 days, the preferred distance between the wind farm site and integration port is taken as 265km.
- Similarly, to bottom-fixed offshore wind, the general weather conditions around the UK are likely to limit the deployment of the WTGs to approximately 5-6 months of the year.
- Industry feedback is that the installation of the WTG onto the substructure should take several days, followed by commissioning works which should have an allowance of one week.
- Taking the above availability and time allowances into account, along with the assumption of a single integration line, results in an annual rate of 25 units per integration facility. This is equivalent to a 850-1000MW project installed over 2 years, which is similar to current fixed-bottom projects. If larger projects are proposed, it is assumed that these would be undertaken over an extended construction period.

Source: TF FLOW expert input, RHDHV – Technology assumptions document

Port type details (2/3)

A Concrete Substructure Manufacturing Port is a facility where the concrete substructures would be cast and assembled prior to being exported to the integration facility.

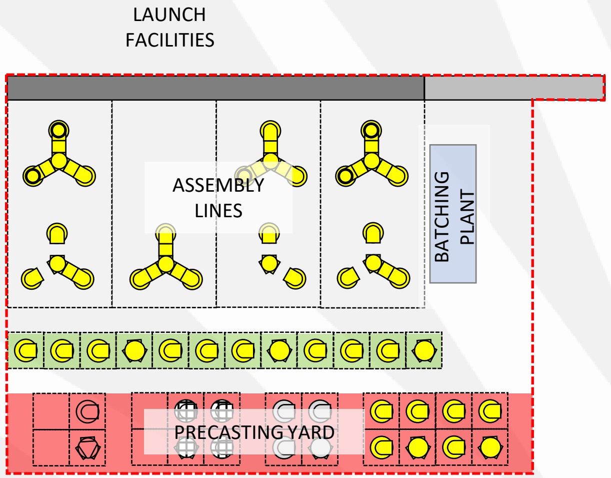
A Concrete Substructure Manufacturing Port is expected to comprise the following facilities:

- Batching Plant – production of concrete to feed the precasting yard and insitu concreting on the assembly lines. Dependent on the local supply chain, raw materials could be sourced locally or imported via quay facilities.
- Precasting Yard - maintenance of formwork, fabrication of reinforcement cages, casting and curing of the bases of the floating substructures.
- Storage Yard – buffer storage of components between the precasting yard and assembly lines to minimise risk of disruption to production.
- Assembly Lines – structures would be moved through the assembly line on skid rails. At the first bay the base of the substructure would be completed. In the second bay, slip-forming of the columns and tower would take place.
- Launch Facilities – upon completion the unit would be transferred into the water via a launch facility. Short-term buffer storage may be required prior to transport to an integration facility or intermediate wet storage facility.

In determining the port infrastructure requirements for an industrialised scale concrete substructure manufacturing port, the following facility parameters are assumed:

- Substructures could be manufactured anywhere in the UK with the completed units wet towed to the relevant integration ports as required, however, there are potential supply chain logistics benefits to locating these facilities in closer proximity.
- Given the potential size and weights of precast concrete components for the substructure, it is deemed practical to co-locate the manufacturing and assembly facilities within the same port.
- Assembly operations would be undertaken year-round, with adequate wet storage facilities provided at either the manufacturing, integration or intermediate storage ports to accommodate the integration port deployment windows.
- The manufacturing process for a concrete substructure is approximately 12 weeks in total, but an assembly line method allows for the subsequent unit to be completed 4 weeks later. Each assembly line can produce approximately 12 units per annum.
- Industry feedback is that an industrialised assembly facility should be capable of producing approximately 50 units annually. Therefore it is estimated that 4 assembly lines would be required.
- Launching of the units would be undertaken utilising a semi-submersible load-out vessel. It is noted that there is a significant tidal variation around the UK and that this represents a potential challenge with regard to the capabilities of a load-out vessel.

Concrete manufacturing port

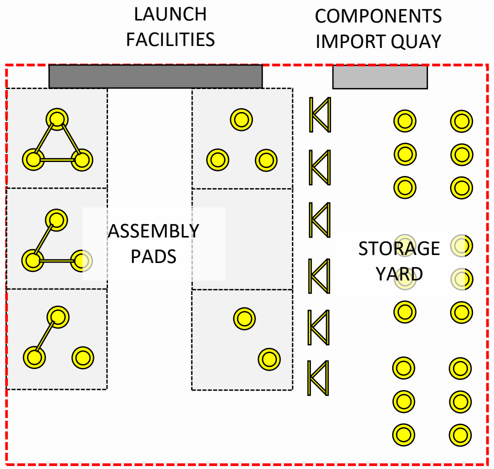


REQUIREMENT	17MW	20MW
Entrance Width (m)	120	130
Air Draft (m)	50	50
Access Channel Width (m)	230	260
Access Channel Water Depth (m below MLWS)	13.0	14.5
Landside Area (ha)	30	40
Storage Area Bearing Capacity (t/m2)	10	10
Assembly Area Bearing Capacity (t/m2)	20	20
Launch Quay Length (m)	520	560
Launch Berth Water Depth (m below CD)	8.5	8.5

Source: TF FLOW expert input, RHDHV – Technology assumptions document

Port type details (3/3)

Steel assembly port



REQUIREMENT	17MW	20MW
Entrance Width (m)	120	130
Air Draft (m)	50	50
Access Channel Width (m)	230	260
Access Channel Water Depth (m below MLWS)	13.0	14.5
Landside Area (ha)	30	40
Storage Area Bearing Capacity (t/m2)	10	10
Assembly Area Bearing Capacity (t/m2)	10	10
Launch Quay Length (m)	275	275
Launch Berth Water Depth (m below CD)	8.5	8.5

A Steel Substructure Assembly Port is an intermediate facility where imported components would be connected to form the floating substructure prior to it being exported to the integration port.

A Steel Substructure Assembly Port is expected to comprise the following facilities:

- Import Quay – import and off-loading of components from fabrication facilities.
- Storage Yard – buffer storage of components between the import quay and assembly lines to minimise risk of disruption to production.
- Assembly Pads – dedicated zones where craneage would be used to erect the components and connections would be made.
- Launch Facilities – upon completion the unit would be transferred into the water via a launch facility. Short-term buffer storage may be required prior to transport to an integration facility or intermediate wet storage facility.

In determining the port infrastructure requirements for an industrialised scale steel substructure assembly port, the following facility parameters are assumed:

- Substructures could be assembled anywhere in the UK with the completed units wet towed to the relevant integration ports as required, however, there are potential supply chain logistics benefits to locating assembly facilities in close proximity to fabrication and integration facilities.
- Component assemblies would be modular and delivered to the assembly port, and connection operations would be minimised as much as possible
- Assembly operations would be undertaken year-round, with adequate wet storage facilities provided at either the assembly, integration or intermediate storage ports to accommodate the integration port deployment windows.
- The assembly process assumes bolted/pinned connections with an assembly period of approximately 6 weeks. Welded connections would require significantly longer assembly periods of approximately 3 months and larger associated areas.
- Industry feedback is that an industrialised assembly facility should be capable of producing approximately 50 units annually. Therefore it is estimated that 6 assembly pads would be required.
- Launching of the units would be undertaken utilising a semi-submersible load-out vessel. It is noted that there is a significant tidal variation around the UK and that this represents a potential challenge with regard to the capabilities of a load-out vessel.

Source: TF FLOW expert input, RHDHV – Technology assumptions document

Based on its offshore and offshore wind position, Scotland could develop ports into integration and manufacturing facilities, available land area is the main limiting factor

Scotland ports

Scotland has a relatively large number of port and harbour facilities serving a diverse range of activities including cargo, O&G, renewables, fishing, ferries, shipbuilding and cruise.

The O&G industry has formed a significant part of the Scottish economy since the 1970's and consequently a number of ports along the east coast have developed to support this industry.

The Shetland and Orkney Islands have deep water facilities for exporting O&G. Facilities in the Cromarty Firth region, initially developed for the construction of oil rigs but now support servicing and storage as well as Ports in the North-East region such as Aberdeen and Peterhead, are major hubs for supply and logistics. On the west coast, facilities at Kishorn and Hunterston were developed to build large oil platforms with Kishorn still being used for O&G this purpose. Related to this, the decommissioning of North Sea infrastructure is expected to be a significant market over the coming years.

Scotland remains at the forefront of the developing offshore wind industry in Europe and ScotWind, the world's largest floating offshore leasing round, represents a massive step forward in delivering an energy revolution. Consequently, ports and harbours have developed to support the construction and O&M activities. Similarly, to O&G, most of the bottom-fixed wind farms have been developed in the North Sea with large ports on the Cromarty Firth providing staging and marshalling services. The rise in offshore wind deployment has seen ports undertake infrastructure projects to service industry requirements and further developments are planned at a number of ports to realise the opportunities around floating wind.

Integration ports

For the base case deployment scenario there would be a requirement for at least **3 facilities** in the Scottish region capable of **providing integration services** on an industrialised scale **from 2030 onwards.** Prior to 2030, industrialised scale integration facilities would not be required.

No current port facilities were identified in the region that fulfilled all of the infrastructure requirements for an industrialised scale integration facility.

Four ports have been identified which could be developed to provide industrialised scale integration facilities to support deployment off the **east coast** of Scotland. Generally, these ports either already have facilities that are used to support the deployment of bottom-fixed offshore wind or are planning FLOW facilities.

Four ports have been identified which, with varying degrees of investment, could be developed to provide industrialised scale integration facilities to support FLOW deployment off the **west coast** of Scotland. Two of these ports are in the process of developing facilities to support FLOW and the other two facilities have significant potential. **Ports along the west coast are less developed** due to lesser deployment of bottom-fixed winds.

The key limitations of the existing port infrastructure are based around the significant larger width and depth of the floating substructures increasing access channels and berth requirements. Additionally, at most existing port facilities there is limited available land area to accommodate the long-term industrialised scale deployment of FLOW.

Taking into account reduced port requirements around landside areas and access channel water depths that could be associated with a reduced throughput of FLOW units, there are still only a limited number of ports that could host integration activities prior to 2030.

Manufacturing & assembly ports

It is estimated that there would be a requirement for at least 1 steel substructure assembly facility and 1 concrete substructure manufacturing facility at industrialised scale from 2030 onward.

No current port facilities were identified in the region that fulfilled all of the infrastructure requirements for an industrialised scale steel assembly or concrete manufacturing facility.

Four ports in the east have been identified which could be developed to provide industrialised scale assembly/manufacturing facilities to support FLOW deployment off the east coast of Scotland.

Four ports in the west have been identified which, with varying degrees of investment. could be developed to provide industrialised scale assembly/manufacturing facilities to support FLOW deployment.

It is noted that **these facilities are the same as those identified to support integration** and therefore there is potential that these activities would be in competition to develop the same port locations.

The key limitation of the existing port infrastructure that has been identified is the available landside area. Generally, a significant amount of open space is required in order to construct and move these large substructures in an industrialised production line.

Taking into account reduced port requirements around landside areas and access channel water depths that could be associated with a reduced throughput of FLOW units, there are still only a limited number of ports in Scotland that could potentially host assembly/manufacturing activities prior to 2030.

Given the small number of units to be assembled/manufactured it may possible in the short term to adopt alternative approaches utilising dry docks or floating platforms in order to maximise the available port options.

For the Celtic Sea, there is a limited number of ports that are currently economical due to limited deep-water access, incentives should come from higher regional deployment

Celtic Sea

The Celtic Sea region is generally bordered by Wales and South-West England.

There are a diverse range of port and harbour facilities in the region serving activities including shipbuilding/ship repair, cargo, liquid bulk, dry bulk, aggregates, steel, tourism & leisure, ferries, and renewables.

Due to the water depths in the Celtic Sea, there has not been any significant development of fixed-bottom wind in the region and subsequently there has been no economic incentive for ports to develop facilities to support this industry. A small number of ports, particularly in the north Wales region have supported activities associated with the deployment of fixed-bottom wind farms in the Irish Sea.

There are a limited number of ports in the region that have deep water access required to support industrialised scale FLOW activities. Additionally, there are a number of more limited port facilities that could accommodate routine O&M facilities to support FLOW deployment.

Ports in the region are aware of the opportunity presented by the development of offshore floating wind and a number of ports are actively seeking to develop facilities in order to support this.

Integration ports

For the base case deployment scenario of 3GW by 2030 it is estimated that there would be a requirement for at least 1 facility in the Celtic Sea region capable of providing integration services on an industrialised scale (minimum 25 units per annum each) from 2030.

No current port facilities were identified in the region that fulfilled all of the infrastructure requirements for an industrialised scale integration facility.

Three ports have been identified which, with varying degrees of investment, could be developed to provide industrialised scale integration facilities to support FLOW deployment in the Celtic Sea. Generally, these ports are aware of the opportunities around FLOW and are in the process of planning facilities to support floating offshore wind deployment.

The key limitations of the existing port infrastructure are that sufficient quayside facilities and landside areas have yet to be developed in order to support the industrialised scale of FLOW deployment.

For the base case deployment scenario of 3GW by 2030 the magnitude of FLOW units to be deployed regionally prior to 2030 is 3 in 2027, 6 in 2028 and 12 in 2029.

Taking into account reduced port requirements around landside areas and access channel water depths that could be associated with a reduced throughput of FLOW units, there are still only a limited number of ports in the Celtic Sea region that could potentially host integration activities prior to 2030. The key limitation for these facilities is the development of facilities that would allow deployment of limited numbers of FLOW units and would require some level of investment to achieve this

Manufacturing & assembly ports

For the base case deployment scenario of 3GW by 2030, it is estimated that there would not be a requirement for a steel substructure assembly facility or a concrete substructure manufacturing facility operating at an industrialised scale up to 2030 in order to serve the deployment of FLOW in the Celtic Sea region.

No current port facilities were identified in the region that fulfilled all of the infrastructure requirements for an industrialised scale steel assembly or concrete manufacturing facility.

Three ports have been identified which, with varying degrees of investment, could be developed to provide industrialised scale assembly/manufacturing facilities to support FLOW deployment in the Celtic Sea. It is noted that these facilities are the same as those identified to support integration and therefore there is potential that these activities would be in competition to develop the same port locations.

The key limitation of existing port infrastructure that has been identified in supporting assembly/manufacturing activities is the available landside area. Generally, a significant amount of open space is required in order to construct and move these substructures in an industrialised production line.

For the base case deployment scenario of 3GW by 2030 the magnitude of FLOW units to be deployed regionally is 3 in 2027, 6 in 2028, 12 in 2029 and 29 in 2030. Therefore, up to 2030, industrialised scale assembly and manufacturing facilities would not be required, although they would need to be in development, so they were available to meet the need.

Taking into account reduced port requirements around landside areas and access channel water depths that could be associated with a reduced throughput of FLOW units, there are still only a limited number of ports in Celtic Sea that could potentially host assembly/manufacturing activities. Given the small number of units to be assembled/manufactured it may possible in the short term to adopt alternative approaches utilising dry docks or floating platforms in order to maximise the available port options.

Integration ports are assumed to be in proximity of projects in initial stages, while UK ports outside the region have the potential to be positioned as manufacturing ports

Rest of UK

The remainder of the UK has a wide variety of port facilities, a number of which have supported fixed-bottom offshore wind deployment.

In Teeside, the development of the Teesworks estate is underway which has the potential to support offshore wind activities. The Able Seaton yard has previously been used to support O&G activities.

On the Humber, Greenport has supported the deployment of fixed-bottom offshore wind and there is a planned development of the large scale Able Marine Energy Park.

There are also plans to develop a new deep water facility at Harwich to support offshore wind.

All these facilities are well located to support the deployment of offshore wind in the North Sea and would generally be considered to be too distant from potential floating offshore wind farms in the Scottish and Celtic Sea regions to serve as integration facilities. However, these facilities could potentially support manufacturing and assembly activities for projects nationwide, and are also able to develop sufficient scale based on fixed bottom offshore wind and additional project cargo transport.

Additionally, a marshalling facility was established in Belfast to support the deployment of fixed-bottom offshore wind in the Irish sea. This use of this facility to support offshore wind has since been discontinued. However, there is still the potential to repurpose and expand this facility to support manufacturing and assembly activities for projects nationwide.

Integration ports

- Integration of WTGs onto floating substructures is assumed to be done at port facilities that are in proximity of the project site.
- The ports in Scotland and the Celtic Sea region that are viable in terms of project proximity have been assessed, while integration ports in other regions outside these areas are not assumed as feasible or attractive up to 2030.
- In the long-run, large integration hubs that are able to be successful with an holistic view on the market. This will involve positioning themselves to grow on the back of a combination of fixed-bottom offshore wind, decommissioning, offshore services and FLOW, could develop as large hubs also servicing FLOW further away from the Scotland and Celtic Sea area.
- It should be assessed in the next phase of this project if those concepts would be a viable alternative to having local/regional integration hubs.

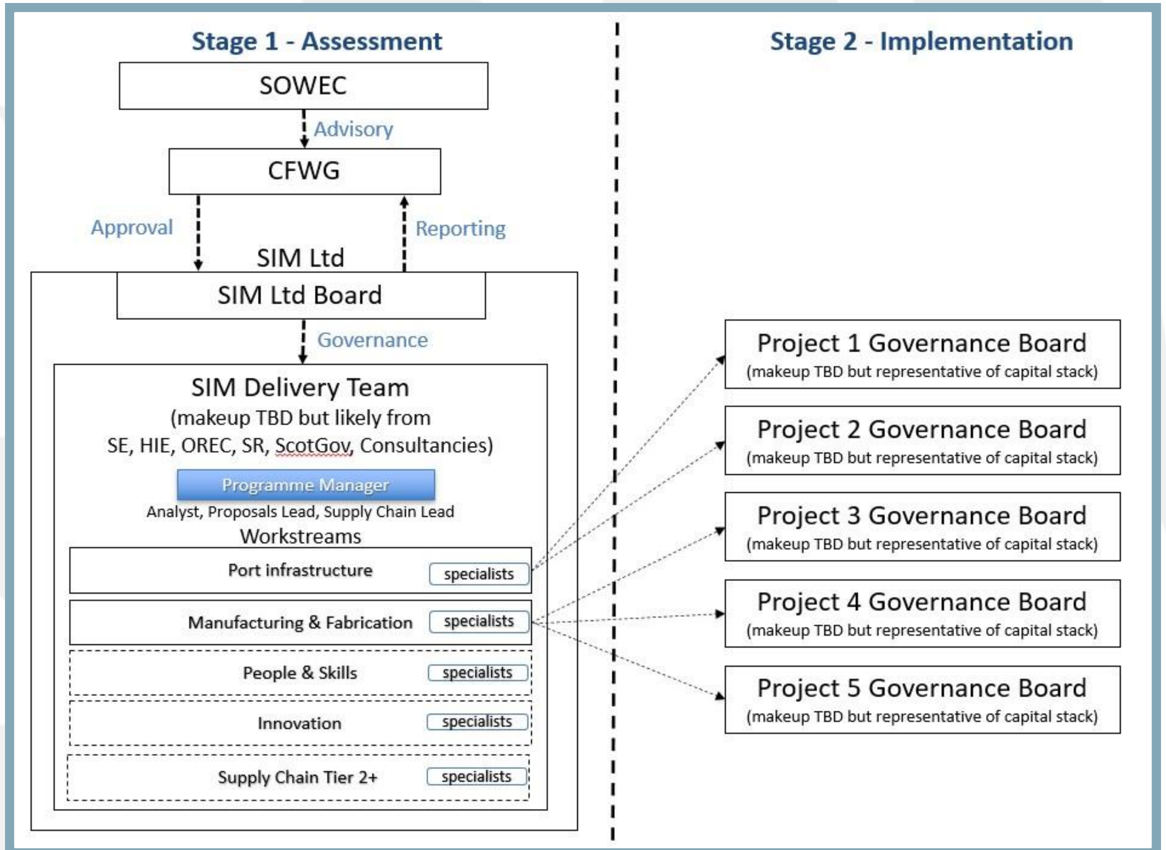
Manufacturing & assembly ports

- For the base case deployment scenario of 3GW by 2030, it is estimated that there would be a requirement for at least 1 steel substructure assembly facility and 1 concrete substructure manufacturing facility operating at an industrialised scale (minimum 50 units per annum each) from 2030 to serve the deployment of FLOW nationally.
- No current port facilities were identified in the UK that fulfilled all of the infrastructure requirements for an industrialised scale steel assembly or concrete manufacturing facility.
- Five additional ports have been identified which, with varying degrees of investment, could be developed to provide industrialised scale assembly/manufacturing facilities to support FLOW deployment nationwide.
- These same ports could be utilised to support assembly/manufacturing activities for FLOW deployment up to 2030.
- Manufacturing and assembly could also be done from multiple locations, including cross-border locations. The use of a combination of ports and diversified supply options are very project dependent. Developers and contractors will look into ways to optimise the logistic cost, aim to de-risk supply and secure sufficient capacity for project execution.

Scottish developers have been working through SOWEC on a Collaborative Framework. 2023 will see delivery of a Strategic Investment Model (SIM) to identify and then drive action on infrastructure priorities

Case study: Collaborative Framework

- At end-2020 the Scottish Offshore Wind Energy Council (SOWEC) commissioned the independent *Strategic Investment Assessment* report to identify priorities for growing the offshore wind supply chain in Scotland. Launched in August 2021, the SIA set out 5 recommendations. The SIA called for the offshore industry to "*come together and work in a more collaborative way, both to help focus activity and investment in Scottish ports, but also to facilitate more meaningful engagement between Scottish suppliers and tier one manufacturers and installers*."
- Shortly after ScotWind leases were announced, all leaseholders were written to by the First Minister and invited to join SOWEC's Collaborative Framework Working Group (CFWG). The CFWG first agreed a Charter which was signed by all participants in April 2022.
- The CFWG has been working to turn the collaborative goal into practical action capable of delivering results, while bringing benefit to participating developers and the supply chain. It was recognised that implementing the Collaborative Framework would require dedicated resources backed by a long-term commitment and an organisational structure with suitable governance to ensure that developers and government would benefit from the collaboration.
- Since August the CFWG has been working on its Strategic Investment Model (right). The CFWG agreed the SIM structure by end of 2022, and agreement to proceed to the next stage was secured by all ScotWind developer boards by end January 2023.
- The SIM will focus on identifying and prioritising the most strategically important investment opportunities. In the first year of its operations, this means infrastructure and manufacturing.
- The SIM will be implemented through a full-time delivery team that carries out analysis of sector requirements and develops strategic project proposals for the large-scale investment in ports, manufacturing and supply chain that is required to deliver the pipeline of Scottish offshore wind projects.
- The SIM aims to:
  - Build a holistic view of Scottish infrastructure needs while being cognisant of UK supply chain status within a global context.
  - Undertake assessment of investment projects proposed by CFWG members with a view to compiling a list of investment options to allow all parties to choose to opt into Stage 2 on a case-by-case basis.
  - For the first year at least, it will maintain a focus on Ports and Tier 1 manufacturing infrastructure.
- The SIM will not (a) undertake investment, (b) commit CFWG members to investing in certain projects, or (c) impose any financial obligation on CFWG members beyond annual membership cost.



Stage 1 - Assessment

SOWEC

Advisory

CFWG

Approval

Reporting

SIM Ltd

SIM Ltd Board

Governance

SIM Delivery Team
(makeup TBD but likely from
SE, HIE, OREC, SR, ScotGov, Consultancies)

Programme Manager

Analyst, Proposals Lead, Supply Chain Lead

Workstreams

Port infrastructure — specialists

Manufacturing & Fabrication — specialists

People & Skills — specialists

Innovation — specialists

Supply Chain Tier 2+ — specialists

Stage 2 - Implementation

Project 1 Governance Board
(makeup TBD but representative of capital stack)

Project 2 Governance Board
(makeup TBD but representative of capital stack)

Project 3 Governance Board
(makeup TBD but representative of capital stack)

Project 4 Governance Board
(makeup TBD but representative of capital stack)

Project 5 Governance Board
(makeup TBD but representative of capital stack)

- ➢ The two-stage process enables all developers to take part in Stage 1 on equal terms. Developers will then choose which projects to join in Stage 2
- ➢ SIM Ltd will manage Stage 1 project assessment and assist in the transition to Stage 2.
- ➢ Subsequent investment & implementation will be undertaken by companies contributing to the capital stack of projects in Stage 2.

Source: SOWEC

Port investment methodology

Approach to establish investments

A. Base Line

Undertaking a full assessment of all potential integration and assembly/manufacturing ports is too extensive and therefore we have utilised information for a number of high potential ports, based on RHDHV knowledge, to establish base line information. This baseline information has then been evaluated against the identified port requirements to determine **representative infrastructure expansion requirements for an integration and an assembly/manufacturing port**.

B. Establish CAPEX levels

Based on the determined infrastructure expansion requirements, port investment levels will be established. These investments levels are based on in-house RHDHV knowledge, benchmarked against available port investment information and announcements

C. DEVEX and OPEX

Expected operational and development expenditure figures will be based on industry parameters and key figures.

D. Ranges and sensitivities

The estimates aim to provide an order of magnitude of port investment that is representative of each port type. The cost data developed is indicative of similar types of structures/works and therefore is presented as cost ranges, rather than a single point value. It is noted that consideration of individual ports may result in investment requirements outside of this range due to site specific circumstances.

E. Stakeholder input

The investments ranges will be tested with a wide group of experts and stakeholders to assure a complete overview and adequate investment figures.

GVA methodology

Economic benefit scope

FLOW development

Estimation of the **additional economic value of FLOW for the UK** based on the **expected DEVEX, CAPEX and OPEX over time** for the aspired high case scenario **compared to the business-as-usual scenario**

Technology scenario | **Deployment scenario** | **Learning rate**

Amount x type of technology x Cost for FLOW deployment x UK expected share = Economic Value of FLOW development

Turbine sizes | **Deployment scenario** | **Learning rate**

+

Port development

Estimation of **additional economic value of the identified port interventions** based on the expected port capacity required to reach FLOW scenarios and the expected investments levels identified for integration and manufacturing ports

Port requirements | **Port capacity need** | **Port interventions**

Port need to deploy amount and types in the right location at the right time

Number of ports | **Investment range** | **OPEX assumptions**

=

Economic benefits

Sum of the expected economic value will be translated into **Gross Value Added for the UK** by using key Green Book parameters for key output figures

Gross Value Added parameters and job creation figures

Translation into:
Economic Benefit ranges
Job creation ranges
Benefit cost ratio

GVA model and output

GVA results

Input
Key figures

- ✓ Aspired high case deployment scenario of 5GW, extrapolated to 34GW in 2040 and 150GW in 2050.
- ✓ Use of deployment scenario, technology assumptions (turbine size, foundation types) and sector learning rates to quantify FLOW benefit development over time.
- ✓ Estimation of FLOW UK content of DEVEX (~90%), CAPEX (~50%) and OPEX (~75%) based on established industry parameters for individual activities.
- ✓ Estimated port capacity requirements towards 2040.
- ✓ Identified DEVEX, CAPEX and OPEX spend for ports per category.
- ✓ Spread of port spend over time: DEVEX in the first year, investments in year 2 – 4, OPEX as of year 5.
- ✓ Estimation of port spending share in the UK based on UK position in development, construction and operations:
  - DEVEX activities range between: 75 – 100%
  - CAPEX activities ranges: 25 – 50% for marine civil, 100% for onshore civils, 10% for cranage
  - OPEX activities range between 75 – 100%
- ✓ Greenbook discount factor of 3.5% and all prices in real prices to calculate the Net Present Value
- ✓ Decommissioning is not considered as part of this assessment, as it is not expected before 2040

Model
Methodology & assumptions

- The estimation of the economic benefits is based on a purposedly-built tool developed by BiGGAR Economics
- Each contract represents an increase in turnover of that company, generating an increase in economic impact.
- For each transaction, an economic sector was assigned, e.g. construction, and turnover to GVA/turnover per employee ratios were applied to estimate the direct impact .
- Spending in the supply chain (indirect impacts) and spending by staff (induced impacts) were captured by applying Type I and Type II multipliers[1]
- The methodology is Green Book Compliant on additionality
- In this model the additional economic value is determined by taking the difference between the aspired ambition and the business-as-usual (deadweight) scenario expected without intervention

Methodology

Total investment

Estimated Contract Value by Type

Estimate Contract Content by Geography

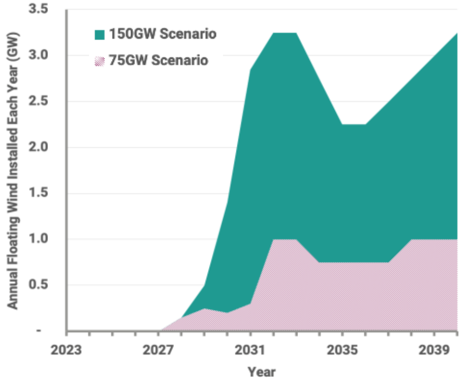
Convert Contract Values to FTEs

Estimate GVA from FTEs

Estimate Supply Chain Impacts

Estimate Induced Impacts

Additional FLOW considered



Output
Estimated total GVA impact

- ➢ The development of FLOW in the UK in the high ambition scenario is expected to result in a total expenditure of £56 billion. This is equivalent to £1.7 billion for every GW of floating offshore wind. The total additional GVA impact of this roadmap is £26.6bn (difference between the total impact and the business-as-usual scenario).
- ➢ By 2040, it is estimated that the port investment will have generated a present value benefit to 2040 of ~£18bn. Using a sensitivity for a lower deployment scenario the benefits would lead to a NPV of £14 billion.
- ➢ The benefits of the investment in port infrastructure are significantly greater than the costs. As a result, the benefit cost ratio (BCR) ranges between 3.4:1 and 4.3:1 and the UK will generate ~£3-4 of GVA for every £1 it invests in port facilities to support the floating offshore wind sector.

Total economic benefits

Aspired high case scenario GVA results	£bn
Total expected expenditure	56.0
Gross GVA FLOW aspired high case scenario	**40.2**
Deadweight GVA under business-as-usual scenario	-13.7
Net GVA Impact	**26.6**

Benefit cost ratio of investments

NPV Costs	NPV Benefits	Ratio
£ 4 bn	£ 18 bn	4

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1) ONS (2021), UK Economic Multipliers 2017

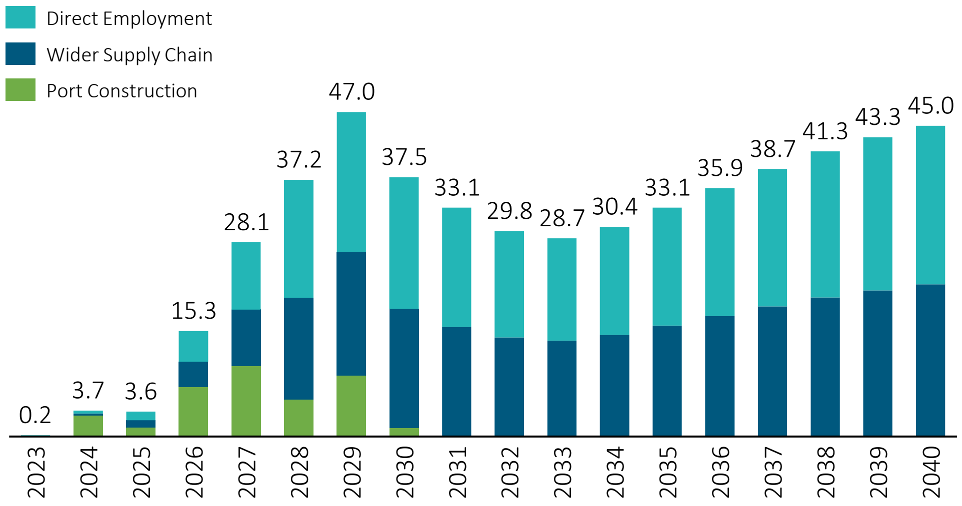
2) This analysis does not consider additional value and synergies with existing activities in fixed bottom offshore wind or with overseas offshore wind opportunities, which would increase the figures further.*

Job creation details

Job creation

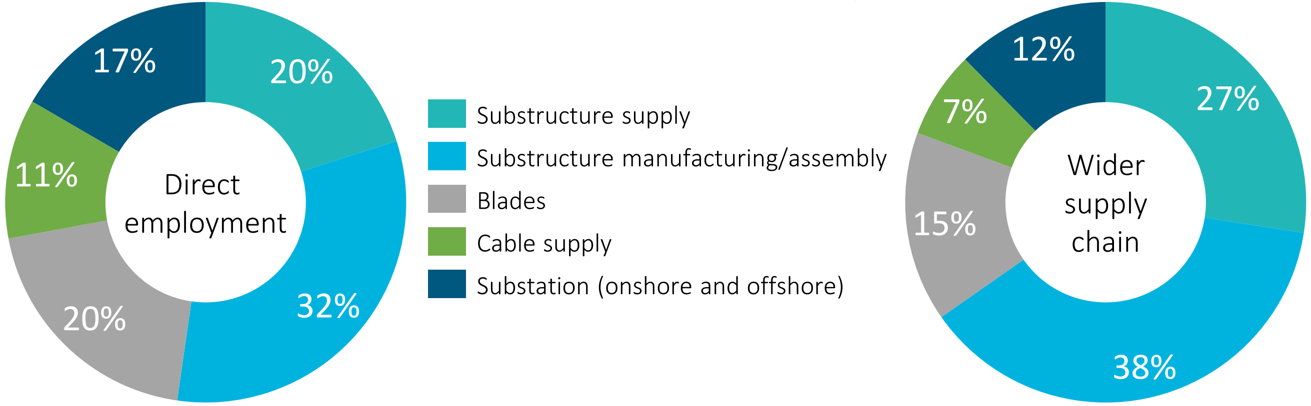
- Over the medium term, to 2040, the floating offshore wind sector will support over 40,000 jobs across the UK. Employment is expected to grow steadily in the 2030s as the level of annual deployment increases and there is a greater demand for O&M activities to service the growing installed capacity.
- **In line with the aspired high case scenario, employment in FLOW is expected to peak in 2029 at 47,000 jobs across the UK, including around 8,000 jobs in port construction. On average, port construction will support around 5,300 jobs per year between 2025-2030.**
- The majority of the employment in the floating offshore wind sector will be linked to the development and construction of the projects, supporting the 2 or 3 GW of capacity that will be added each year.
- **When compared with the BaU scenario, the additional jobs created by implementing the recommendations from this roadmap ranges between 23,000 to 30,000 .**
- The main opportunities by contract area are associated with the construction of the floating substructures. On average, it is expected that the direct and wider supply chain impacts linked to this construction activity would support an average of 5,200 jobs between 2030 and 2040.
- Direct jobs are generated directly from the port and FLOW project activities, indirect jobs are generated by supplies and services in the supply chain, while induced jobs are created by additional personal spending and wider economic gains as a result of value generated from these port and FLOW activities.
- **Due to the deployment scenario used to drive 5GW of FLOW capacity in 2030 and the stable construction expectations towards 2040, the job creation grows unnaturally fast and spikes towards 2030. In practice, these figures will show a more gradual development.**
- **As job creation is pushed by our ambitious scenario and early stage port construction this spike and job development over time is not related to the sustainability of the employment created. It does however, highlight the incredible task we have on our hand in terms of skills to service the 5GW by 2030 target.**

Total job annual job creation towards 2040 based on the aspired high case scenario (number of jobs x1,000)



Job creation	x1,000
Average gross employment impact	29.5
Average deadweight employment	9.3
Average additional jobs created	20.2
Port specific	
Average port construction	5.3

UK employment opportunities by contract type (average 2030 – 2040)



Source: Biggar Economics March 2023, RUK FLOW Industrialisation Roadmap, Port Infrastructure Report, Economic Impact Methodology

Economic benefits - Sensitivities

Lower deployment scenario

- There is considerable uncertainty around the level of deployment in the floating offshore wind sector in the UK. Therefore, a sensitivity analysis was performed that considered a reduction in deployment compared to the base scenario.
- In particular, the sensitivity analysis was performed on a deployment scenario with a 20% reduction in annual build out. Therefore, at its peak, in 2040, 2.8GW of floating offshore wind becomes operational, rather than 3.5GW in the base scenario.
- In this scenario, by 2030 there would be 4GW of operational floating offshore wind in the UK, rather than 5GW in the base scenario. By 2040 there would be 27GW of operational floating offshore wind in the UK, rather than 34 GW in the base scenario.
- The reduction in the deployment of floating offshore wind projects in the UK by 20% would result in a reduction in the turnover of UK based organisations and the GVA and employment that would be supported by this turnover. In particular, in this scenario, the additional port investments would facilitate:
    - Cumulative additional turnover in UK organisations with a NPV of £18.5 billion to 2040;
    - Cumulative additional GVA in the UK with a NPV of £13.9 billion to 2040; and
    - 23,480 additional jobs supported in 2040.
- This impact is lower than is described in the base case, however it still represents a greater return than the original investment in port infrastructure. The Benefit Cost Ratio in this scenario is 3.4, compared to 4.3 in the base scenario.

	Aspired high case Scenario	Low Deployment Scenario	Difference
Turnover (NPV)	£24.0 bn	£18.5 bn	£5.5 bn
Additional GVA (NPV)	£17.9 bn	£13.9 bn	£4.0 bn
Additional Jobs in 2040	29,830	23,480	6,350
Benefit Cost Ratio	4.3	3.4	0.9

Lower UK content

- The core scenario analysis assumes that the offshore wind sector in the UK will achieve and maintain 60% UK content, in line with the targets outlined in the UK sector deal. Analysis by BVG Associates suggests that in a 60% UK content scenario across the entire offshore wind sector, covering both fixed and floating projects, the UK content of floating projects is expected to be slightly higher, 62%. Similarly, in the 55% UK content scenario, the level of UK content for floating offshore wind is expected to be 60%. This is shown in Table 5, which highlights variation in the level of foundation construction as the only variable that differs between the 60% UK content scenario and the 55% UK content scenario.
- For the purposes of the scenario analysis, it is assumed that there is a 5% reduction in UK content for floating offshore wind projects, specifically it is reduced from 62% to 57%. In addition to a reduction in the share of floating foundations that are constructed in the UK, there is also a reduction of UK content linked with cable laying and general operations and maintenance.
- The reduction in UK content of floating offshore wind projects would result in a reduction in the turnover of UK based organisations and the GVA and employment that would be supported by this turnover. In particular, in this scenario, the additional port investments would facilitate:
    - Cumulative additional turnover in UK organisations with a NPV of £22.3 billion to 2040;
    - Cumulative additional GVA in the UK with a NPV of £16.3 billion to 2040; and
    - 27,010 additional jobs supported in 2040.
- This impact is lower than is described in the base case, however it still represents a greater return than the original investment in port infrastructure. The Benefit Cost Ratio in this scenario is 4.0, compared to 4.3 in the base scenario.

	Aspired high case scenario	Low UK Content Scenario	Difference
Turnover (NPV)	£24.0 bn	£22.3 bn	£1.7 bn
Additional GVA (NPV)	£17.9 bn	£16.4 bn	£1.5 bn
Additional Jobs in 2040	29,830	27,010	2,820
Benefit Cost Ratio	4.3	4.0	0.3

Source: Biggar Economics March 2023, RUK FLOW Industrialisation Roadmap, Port Infrastructure Report, Economic Impact Methodology