Ports: a key enabler for the floating offshore wind sector

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The industry has drafted this guidance to present the state of play of floating wind, including the main differences and similarities between floating platforms. This intends to be a discussion-starter for stakeholders, including ports, developers, and technology providers. The document summarises information publicly available and the view of experts from WindEurope's Floating Wind Working Group and Ports Platform. Neither WindEurope nor its members shall be responsible for any loss whatsoever sustained by any person who relies on this publication.

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Windfloat Atlantic construction, Courtesy of Navantia

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EXECUTIVE SUMMARY

The achievement of Europe's decarbonisation goals requires stepping up the deployment of bottom-fixed and floating offshore wind to at least five times the current installed capacity just in the next decade. Floating wind could represent nearly one-third (100-150 GW) of the full capacity installed by 2050. Ports would need to increase their capacity to build and service at least 500 MW/year of Floating Offshore Wind (FOW) projects in this decade and 4 to 7 GW/year from 2030 onwards.

Upscaling port infrastructure and investments need to be aligned with long-term view. Today there are many floating wind designs competing for commercial deployment which will need different infrastructure requirements. Floating wind as opposed to bottom-fixed carries most of the assembly onshore. Therefore ports will need expansion of their land, quay reinforcement, storage for components, carrying capacity, cranes and other retrofits to host mass production of floaters and other turbine components.

The floating wind industry could use between 60-70% of the existing supply chain, originally deployed for bottom-fixed offshore wind. This could accelerate its commercialisation. It also means that R&D could be best used to fine-tuning certain components, like optimising and adapting dynamic cables, mooring systems and other auxiliary services for mass scale production. This would reduce even further the cost of floating wind.

Europe should develop a clear strategy for the development of ports. This would maximise the whole supply chain efficiency of offshore wind. Space is and will become a bigger issue for ports, not only on land, but also on the water. To overcome this, ports will require new strategies and collaboration regionally. Ports could support wind turbine manufacturing, foundation production, installation, operation and maintenance of wind farms across regions to serve several projects with the right investments and policies.

National Governments should continue to provide long term visibility for stakeholders through a clear auction schedule dedicated to floating offshore wind alongside an industrial strategy that includes ports as a key pillar. Policies should focus on bringing this technology to commercial scale, investing in R&I, port infrastructure, and holding technology-specific auctions with long-term revenue stability support.

Earmark support for port infrastructure to develop projects and supply chain at regional level across several Member States. The EU Recovery Plan should prioritise the physical infrastructure required by the wind energy supply chain for bottom-fixed and floating projects.

1. INTRODUCTION

Offshore wind creates opportunities for ports. Ports can use offshore wind to increase and diversify their activity portfolio. Ports and local stakeholders are now pushing to develop regional strategies for green technologies to create local employment and industrial activity in light of decarbonisation targets. Now is the time for a long-term vision to help maritime regions and harbours position themselves in the long run, and to ensure that ports can enable a larger deployment of offshore wind and other technologies.

Port activities for offshore wind are in competition with more traditional activities, such as container transport, fishing and tourism. The offshore wind business can guarantee activities on the long run but will most probably require specific investments to be put in place (in terms of quay and ground reinforcements, for instance). Some European ports have made significant investments to become active players in the offshore wind sector. These specific investments required long-term government commitments, such as those found in the binding 2030 targets of the UK, the Netherlands and Germany. These and other national plans are now reflected in the National Energy and Climate Plans, which cumulatively foresee 111 GW of European offshore wind by 2030.

Support is now required at European level to help countries and maritime regions to coordinate and generate the necessary investments in offshore wind port infrastructures. In principle, various European funding mechanisms can be used, such as European Structural and Investment Funds (e.g. European Maritime and Fisheries Fund), the Connection Europe Facility and instruments from the European Investment Bank. But political momentum is required to accelerate the decision-making process. This will involve the European wind industry, Member States, the cluster of maritime regions, and the European harbours.

The industry has drafted this guidance to present the state of play of floating wind, the port-related infrastructure challenges associated to each activity and recommendations to accelerate the industrialisation of this nascent industry. It thus intends to be a discussion-starter for stakeholders, including ports, developers, and technology providers.

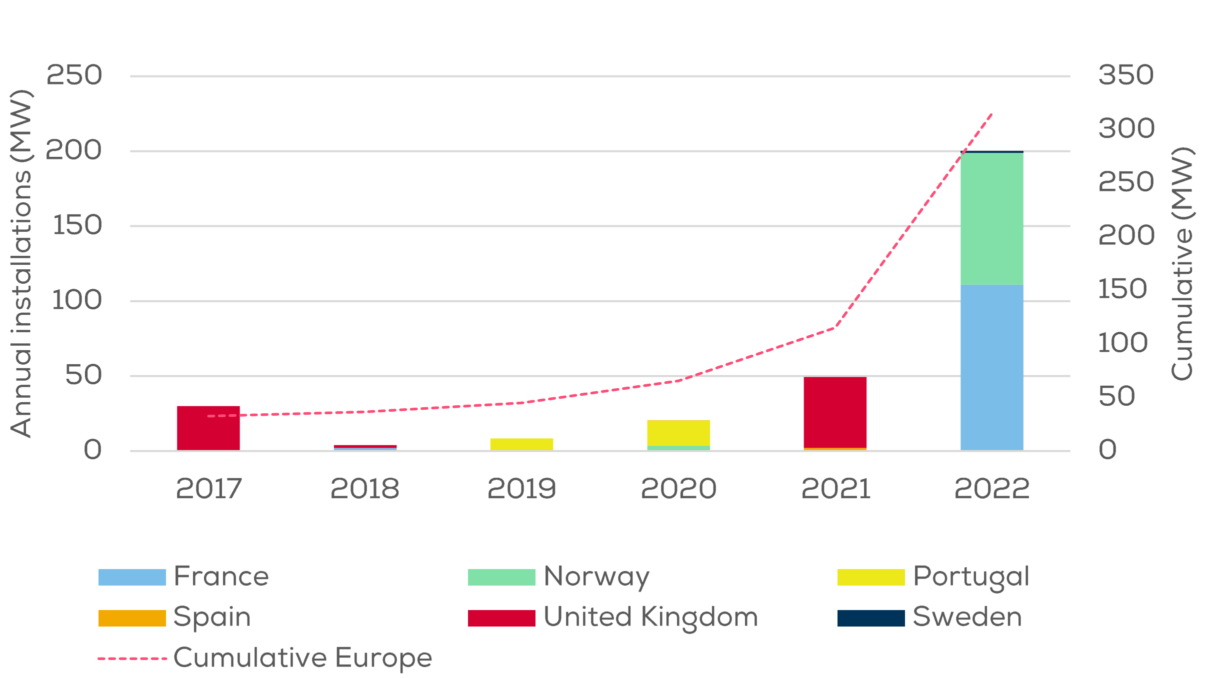
2. FLOATING WIND: STATE OF PLAY

Floating is now a proven technology with demonstrators and projects in Europe and Asia. Today there are 11 projects for a total capacity of 74 MW online, with 62 MW located in Europe. Considering projects under construction and those with all the necessary construction permits, there will be nearly 350 MW by 2022, mostly in Europe. And there are at least 3-7 GW worth of projects that could be commissioned by 2030 if they can secure support.

Europe's offshore potential is huge and there is enough wind resource in European waters to satisfy 100% of Europe's electricity needs. According to (BVG Associates for WindEurope 2017) offshore wind could generate up to 6,000 TWh per year at a competitive cost (€65/MWh or below). About 3,250 TWh could be produced with installations located at water depths below 60m (viable for bottom-fixed foundations), while another 2,750 TWh could be developed at water depths above 60m (viable for floating technologies). This means almost half (45%) is in deep waters suitable for floating offshore wind.

WindEurope has previously stressed the importance of having supportive policies and measures to stimulate Floating Offshore Wind (FOW) growth and full commercialisation. Governments are key to provide stability to the industry by ensuring enough volumes in the National Energy and Climate Plans (NECPs) through recurrent dedicated tenders for floating offshore wind. Currently, France is the only country with FOW tenders in the pipeline for the next decade, with the aim to deploy 750 MW through dedicated tenders and the ambition that floating will be able to compete with bottom-fixed projects in other technology-neutral tenders by 2030.

Figure 1. Timeline of floating projects in Europe (2017 - 2022)



2.1 FLOATING FOUNDATIONS

There is a vast amount of geographical locations with water depth or soil conditions that are unsuitable for bottom-fixed offshore wind. Floating wind allows to build projects further from the coast, where competition for space is lower. In addition, environmental impacts, especially during construction, are reduced due to the absence of a fixed foundation piled into or sunk on to the seabed.

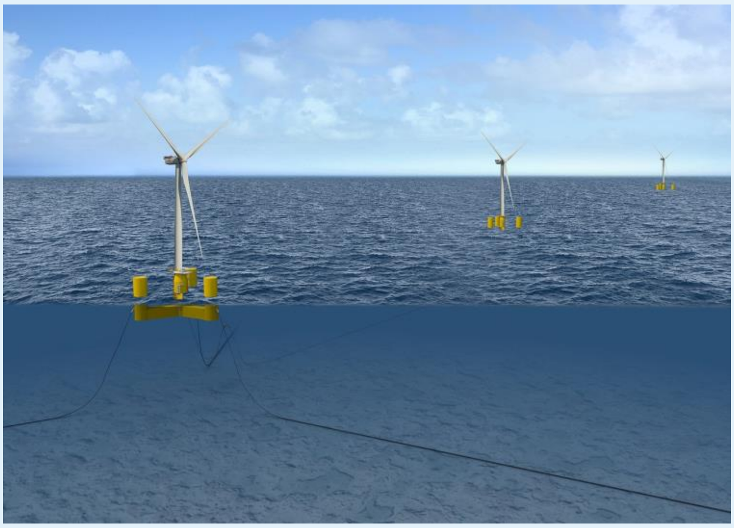
Floating foundations share design principles with other sectors such as the oil and gas sector and the shipping industry. These sectors, with their understanding and control of the buoyancy of objects at sea, directly influenced the development of mooring lines and ballast control mechanisms which now characterise the floating wind industry.

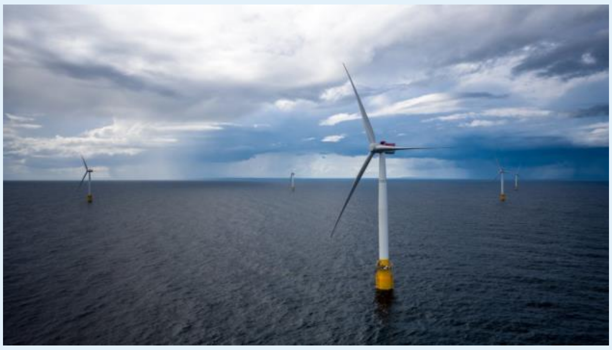
Floating offshore wind technology involves a turbine mounted on a floating structure anchored to the seabed through mooring lines. The floating structure needs to withstand loads from wind, waves, and wind turbine rotation. There are many different floating foundations designs.

The existing foundations have different mechanisms to provide stability and high performance during the long lifetime of the asset. They differ in geometry, shape and material. These parameters also affect the logistics needed to assembly and install each turbine. This requires different approaches for assembly, storage, components mobilisation and other logistics at industrial and port facilities.

There are four main types of floating foundation platforms.

Barge	Examples
A barge is a hull made of either steel or concrete. It is stabilised through its buoyancy (waterplane area). The assembly of the structure is performed onshore and towed offshore using tugboats. Barge structures have a low draught, making them suitable also for shallow waters if needed. The structure is additionally anchored to the seabed using catenary mooring lines or other configurations depending on the water depth. Currently structures weigh around 4,000 tons.	• **DampingPool** (by IDEOL)  **Figure 2.** Floatgen in France (courtesy of Ideol BYTP ECN V. Joncheray) • **SATH** (by SAITEC)  **Figure 3.** BlueSATH operational in Spain (Courtesy of SAITEC – INTEDIG image)

Semi-submersible	Examples
A semi-submersible or semi-sub foundation is a hull with columns connected to each other with bracings. The most common steel design uses three columns, of which one supports the turbine either in one corner or in the centre. The platform uses the buoyancy force to be stabilised when floating. The structure is anchored to the seabed using catenary or taut mooring lines, with a horizontal distance between anchor and fairleads of 450–1,200m. This structure is assembled onshore and, despite its heavy weight, it has a relatively low draught of approximately 10m during transportation. The weight of the structure for a single turbine is around 2,500 tons. Other semi-sub structures are researching the possibility of allocating several turbines in a single platform. A multi-turbine floating platform is a large semi-submersible platform stabilised though buoyancy and supporting more than one turbine.	• **WindFloat** (by Principle Power) **Figure 4.** WindFloat Atlantic in Portugal (Provided by Principle Power. Artist name: Dock90)  • **STAR1** (by Naval Energies) **Figure 5.** Artist's impression of Eoliennes Flottantes de Groix et Belle-Ile (courtesy of Naval Energies)  • **Other:** Nautilus (by Nautilus Floating Solutions); TrussFloat (by Dolfines); Fukushima forward V-shape (by Mitsubishi Heavy Industriesl, Ltd.), Fukushima Forward compact semi-sub (by Mitsui Engineering & Shipbuilding Co, Ltd.), Hexafloat (by SAIPEM); Eolink (by EOLINK), W2Power (by EnerOcean), Hexicon (by Hexicon); FLOW (by FLOW Ocean)

Spar-buoy	Examples
A spar-buoy (or spar) is a cylinder structure. It is stabilised by keeping the centre of gravity below the centre of buoyancy, using a ballast made of one or more heavy materials. This is the structure with the largest draught, between 70-90m once installed, minimising the motions and stabilising the structure. However, this can translate into more complex logistics in the assembly, transportation and installation of the foundation. The structure is anchored to the seabed using catenary or taut mooring lines, with a horizontal distance between anchor and fairleads of 450-1,200m. The assembly of the foundation is performed onshore. It can be towed out to the offshore location. The steel weight of one structure is around 2,500 tonnes before ballasted.	• **Hywind** (by Equinor) **Figure 6.** Hywind Scotland (courtesy of Equinor)  • **SeaTwirl** (by SeaTwirl) **Figure 7.** Artist's impression of SeaTwirl 2 (courtesy of SeaTwirl)  • **Other:** Advanced Spar (by Japan Marine United), TetraSpar (by Stiesdal).

Tension Leg Platform (TLP)	Examples
A TLP is a smaller and lighter floating structure. This results in a higher buoyancy force which requires the anchoring mooring lines to be fully tensioned to provide stability. The TLP has a shallow draught but given the high buoyancy the structure experiences a higher vertical load on the mooring lines and anchors. The TLP floater has a lower footprint on the seabed due to the reduced water column below the structure. There are currently no operational floating turbines using TLP technology. The weight of this platform can be lower than the semi-sub.	• **Inclined-leg TLP** (by SBM Offshore & IFP Energies Nouvelles) **Figure 8.** Artist's impression of SBM Offshore wind floater (courtesy of SBM Offshore)  • **Other:** TLPWind (by Iberdrola).

2.2 ROAD TO COMMERCIALISATION

The Technology Readiness Level (TLR) is a simplified classification to determine the stage of development for different technologies (Hannon, et al. 2019). Table 1 shows a TRL adapted to FOW commercialisation level.

Table 1. Road to Floating Commercialisation level definition

Category	Description
Part-scale demonstration	Formulating and proving of design concept with numerical and computational models. Small- and large-scale prototypes in tanks, laboratory tests and offshore environment. Up to TRL 5
Full-scale demonstration	Full scale prototype in offshore environment in operation. Up to TRL 8-9
Precommercial deployment	Pre-commercial pilot project with 3 to 10 turbines. TRL 9 or above
Commercial deployment	Commercial projects with more than 10 turbines. The project might have 1 or more export lines back to shore with the aid of floating substations. TRL 9 or above

There are currently 50 floating designs in development worldwide (Figure 9). 34 of these are European. Over half of the designs (62%) are semi-submersibles followed by spar-buoys (20%). Most of the foundations (78%) are designed to host a single-turbine as compared to hybrid wave or multiple-turbine platforms. And most of them prefer steel (80%) over concrete, because steel offers faster assembly options with pre-fabrication of parts (Wood Mackenzie 2020). Table 2 includes a list of some of these active floating platforms with the main characteristics and the status of development (TRL).

Figure 9. Active floating platforms worldwide

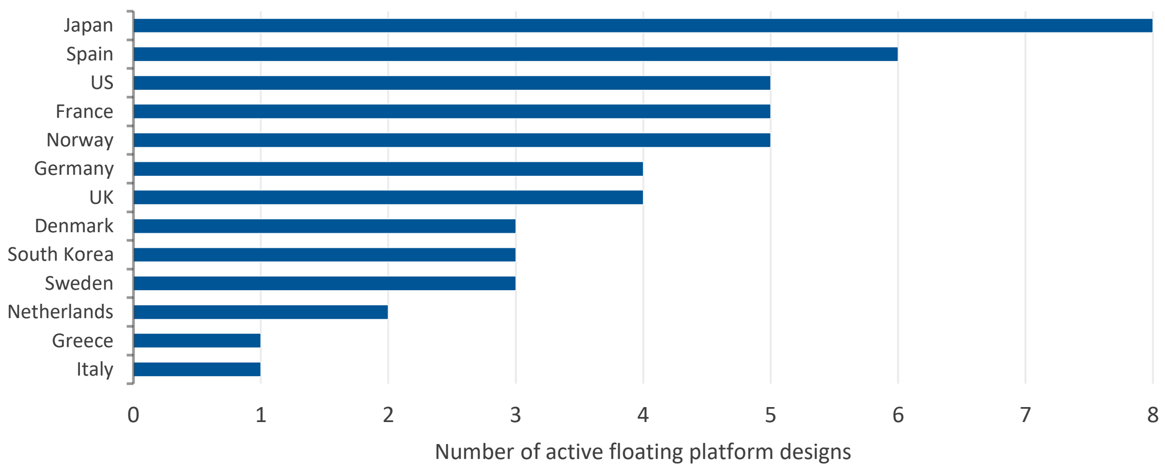


Table 2. Floating platforms in development stages towards commercial scale[1]

	Technology designer/developer	Concept Name	Country	Material	Part-scale demonstration	Full-scale demonstration	Pre-commercial deployment	Commercial deployment	Units installed and cumulative capacity (MW)
Semi-submersible	Principle Power	WindFloat	US	Steel		2011	2019	2025	4 (27.2 MW)
	Naval Energies	Semi-submersible	France	Hybrid			2022	2025	
	Mitsubishi Heavy Industries	MHI 3 column V-shape	Japan	Steel		2016			1 (7 MW)
	Mitsui Eng. & Shipbuilding	Compact semi-sub	Japan	Steel		2013			1 (2 MW)
	GustoMSC	Tri-Floater	Netherlands	Steel		TBD			
	Aqua Ventus Maine	VolturnUS	US	Concrete		2022			
	SAIPEM	HexaFloat	Italy	Steel	2020	2022		2030	
	Nautilus	Nautilus	Spain	Hybrid		2021			
	Dolfines	TrussFloat	France	Steel		2022	2022	2025	1 (0.17 MW)
	EOLINK	EOLINK	France	Hybrid		2022			1 (0.2 MW)
	UoU, Mastek, Unison & SEHO	UOU 12-MW FOWT	South Korea	Steel	2020	2021		2025	
Barge	IDEOL	Damping Pool	France	Concrete		2018	2022	2025	2 (5 MW)
	SAITEC	SATH	Spain	Concrete	2020	2021		2025	1 (0.03 MW)
Spar-Buoy	Equinor	Hywind	Norway	Hybrid	2001	2009	2017	2024	6 (32.3 MW)
	TODA Corporation	TODA Hybrid spar	Japan	Hybrid		2016	2021		1 (2 MW)
	JMU	Advanced Spar	Japan	Steel		2016			1 (5 MW)
	Stiesdal	TetraSpar	Denmark	Steel		2020			
	SeaTwirl Engineering	SeaTwirl	Sweden	Hybrid		2020			1 (0.3 MW)
	ESTEYCO	TELWIND	Spain	Concrete		TBD			
TLP	SBM Offshore & IFP Energies Nouvelles	Inclined-leg TLP	France	Steel			2022		
	GICON GmbH	GICON-SOF	Germany	Steel		TBD			
	Iberdrola	TLPWIND	Spain	Steel		TBD			
	X1WIND	X1WIND	Spain	Hybrid	2020	TBD			
	Hexicon	Hexicon	Sweden	Steel		2021		2025	
	FLOW Ocean	FLOW	Sweden	Steel		2021			

Online or finalised test — Under construction, reached FiD or with all permits granted — Permitting stage

[1] The diagram combines the latest available updates as of August 2020. But this is indicative and the final commissioning date can vary depending on the permitting and financing process of each individual project.

3. PORTS SERVING THE OFFSHORE WIND SECTOR

Ports in the offshore wind business can diversify their harbor functions to support specific activities: manufacturing and assembly of foundations, production of large components (e.g. blades, towers), electrical infrastructure such as the substations, installation, operation and maintenance of wind farms.

The location of ports is crucial for the development of offshore wind. Ports, as land-sea interface, play a key role for the local supply chain, logistics and supporting infrastructure (e.g. storage of components). The availability of vessels and proximity of concession zones has an important impact on costs for both installation and O&M activities. The ability to provide adequate infrastructure and services creates value across the entire value chain and plays an important role in contributing to cost reduction for offshore wind.

In an industry that is growing rapidly in volume of projects, size of wind farms and technology dimensions, ports need to continuously adapt their infrastructure. Investments decisions must rely on future technology perspectives. Larger and heavier turbines will require more space, new facilities and bigger vessels. Those investment for offshore wind facilities can then attract other industries such as hydrogen production and storage, battery storage, chemical industries, waste management and data centres.

Some ports offer services over the entire life cycle of assets, from installation to operation and maintenance (O&M) and decommissioning. They are known as multi-purpose ports. Others just focus on O&M as they don't have the required facilities. Installation ports, for example, rely on a stable pipeline of projects and require important investments in facilities for accommodating and shipping components. O&M ports, serving one or more wind farms for the wind farm lifetime, require less investments in ports facilities. But this does not apply to floating O&M as wind turbines could be towed back to the port for maintenance, requiring a suitable infrastructure at quay.

Selecting a port for upcoming projects and as a base for wider industrial and business activities is a key decision for offshore wind developers. Early involvement of ports in the planning phase of projects increase the chances to reduce project cost and time for delivery, capitalising on ports large expertise on large infrastructure projects, heavy lifting, assembly techniques, etc. However, that's not always the case. Developers might contact a port for a specific project a few months prior to submitting an offer for a tender or even just before the work is due to start. In other cases, a developer might partner with the port for the duration of the installation only and move on to the next project at a different location.

This lack of visibility for the port can lead to challenges in planning strategic investments. Without longer visibility from industry and ultimately from governments on auctions timelines, ports face the choice of making investments without any guarantees of business, risking underutilizing the new infrastructure.

However, so far port operators and their wind customers have benefitted so far from well planned investments to ensure timely delivery of projects.

Unlike bottom-fixed foundations, that rely on large jack-up vessels to assemble the turbines at sea, floating is most likely to be assembled at port. This requires adequate infrastructure such as a heavy-duty cranes, assembly area, and deep draught berth, dry dock or large gantry cranes. These requirements will vary according to the foundation type. It is estimated that from a supply chain perspective around 60-70% of the existing offshore supply chain could be shared from the bottom-fixed to the floating wind sector giving a large advantage for the commercialization of this technology.

Ports can provide different functions for the commercialisation of floating offshore wind according to their facilities and services (BOEM 2016). Each subsection includes a study case and the challenges associated in adapting this activity to floating wind.

3.1 MANUFACTURING COMPONENTS

The introduction of new technologies and the large size of turbines is making road transportation less viable for completed nacelles and blades. Thus wind turbine manufacturers are increasingly looking towards European portside facilities for the manufacturing of nacelles, blades and towers.

The production of commercial floating wind farms requires floating-specific solutions for foundations, dynamic cables, mooring systems and other auxiliary services. Currently these solutions are provided on a project-by-project basis. Experience with the first demonstration projects is helping to refine current designs so that they can be produced at mass scale. Components do not necessarily need to be produced in a port, but logistics costs will be reduced if the manufacturing facility is closer to the assembly area. Most of the floating wind turbines are the same units installed in bottom-fixed foundations, creating an opportunity for wind turbine manufacturing ports to have a larger pipeline at regional level in supplying floating and fixed projects.

Port of Hull, UK

Figure 10. Siemen's Hull wind factory in the UK. Photo: Siemens

Siemens Gamesa Renewable Energy (SGRE) invested £160m in 2016 for the construction of a new harbour at Green Port in Hull, UK, to enable the pre-assembly of turbines prior to installation in the North Sea. This investment, combined with an extra £150m from Associated British Ports, allowed the construction of the state-of-the-art facility which has supplied Dudgeon, Hornsea One and will supply Hornsea Two.

Operations have expanded at Hull's port by taking up new land on the docks for storage, where almost 40 wind turbine blades can be stored. Each blade takes around an hour and a quarter to transport. Work is being done in the early hours of the morning to minimise disruption to the port.

SGRE is planning to apply this model again in France and has signed a 30-year lease in Le Havre for a total area of 36 hectares to build a factory. This industrial unit will deliver the turbines for French offshore wind farms and has a pipeline of over 2 GW, including 5 bottom-fixed wind farms and one floating pilot project. The port factory is expected to start operating by the end of 2021.

Overall, a stable pipeline of 1 GW per year project portfolio over several years sets the right conditions for establishing a new manufacturing site at a port facility.

3.2 FOUNDATION PRODUCTION

Offshore wind foundations, regardless of being bottom-fixed (steel monopiles, concrete gravity bases, jackets) or floating, are large and heavy and once produced is preferable to transport by water. New coastal locations for foundation manufacture will be established to support the expansion of bottom-fixed and floating wind.

The different floaters can be built using steel, concrete or even in a hybrid configuration. This choice will affect some specific parts of the assembly process. In the case of steel, most of the operations will consist of plate cutting, bending, rolling, welding and applying an anti-corrosion coating. On the contrary, concrete structures require a large set-down and quay area to build the foundation by continuously pouring concrete into phases. The manufacturing process can be optimised and reduce cost with the use of prefabricated concrete parts which need to be assembled only.

In both cases the weather windows could affect the manufacturing process. Depending on the port capabilities, manufacture and assembly could take place in the same location to reduce logistical costs. But given the infrastructure characteristics and space available needed by each platform, the industry has used a collaborative approach between ports to carry out the different project activities. Hywind Scotland and Windfloat Atlantic are examples of this approach.

Navantia-Windar has built different foundations for the two projects – spar and semi-sub, with draught needed for assembly as one of the main differences. The construction of five spar units for Hywind Scotland was carried out in the Spanish yard and then sent to Norway, where the turbines were assembled on each floater with a draught of approximately 90 m. For Windfloat Atlantic one semi-sub was built in the yard of Fene and sent to the neighbouring Port of Ferrol for turbine assembly, while the other two units were manufactured by ASM Industries in Portugal (Setúbal and Aveiro). All units reached Viana do Castelo, Portugal for final tow-out to the project location 20km off the coast.

Different floaters will require strategies depending on their specific challenges. Developing strategies for ports to perform together all activities in a floating wind farms will bring not local, but regional benefits.

Port of A Coruña

Figure 11. Shipment of concrete caissons leaving from the port of A Coruña

The Port Authority of A Coruña has recently constructed a new outer port far away from the city centre, with a public port investment close to €650 million. Part of the activities have already been moved to the outer port, but a lot of space is still available for new activities. The port has currently 190 ha of plot of land, more than 100 ha available for the development of new and different business as well as very big drafts, up to 21.85m at the public quay, and large areas of protected waters.

The port can allocate different business opportunities related to offshore wind, including the construction and industrialisation of offshore floating structures, not only in steel, but also in concrete.

The port of A Coruña was selected for the construction of 22 caissons for the quay of Aberdeen port. The same technology could be used for the construction of concrete foundations for floating wind. Different companies are studying the potential of A Coruña to allocate their prototypes at the port. There is also an industrial steel company, Horta Coslada, located just 5 minutes of the main entrance to the port, which has constructed the steel structure for the prototype fix foundation Elisa, from Esteyco, placed in Canary Islands.

3.3 ASSEMBLY

In order to allow the assembly of the foundation pieces and the turbine, direct access to a high capacity deep water dock is required. Assembly ports must provide adequate staging and storage areas. Space is and will become a bigger issue, not only on the landside but also on the water, where heavy components might be stored in floating structures. The increasing size of components and operations shall drive investments in assembly ports. Assembly ports could also provide opportunities for cable-laying, mooring installation and monitoring activities.

Different studies have evaluated the pros and cost of port-side vs offshore operations for the assembly and installation of floating offshore wind turbines. Port-side integration is limited by the availability of cranes, space, draught and carrying capacity. Offshore integration is a more established process (from the bottom-fixed sector) but it is a very challenging lifting procedure heavily dependent of weather conditions at sea. It is also limited by the lifting capacity and height of the installation vessels' crane.

This is naturally subject to change by project, particularly in relation to concept design, site location, environmental conditions and available infrastructure. Barge and semi-sub designs have a shallower draught and greater stability, making them suitable for onshore or quayside assembly of the wind turbine. Once the turbine is mounted on the floater it can be towed and installed to the mooring system (usually pre-installed). Spar and TLP structures have a different assembly process. The spar deep draught makes it more suitable for horizontal transportation, and installation can take place at inshore deep-water location or at the offshore site. The TLP type lacks field experience (full-scale demonstrators) sitting wind turbines, but it could adopt methods similar to semi-sub platforms. The first full scale TLP will be online in 2022 in France.

In general, draught and crane capacity remain a significant constraint, especially when considering the evolution of larger and heavier turbines and substructures. Cranes currently operating in most ports are not large enough to mobilise wind turbines of 10+ MW. New generation cranes will most likely be developed, as their availability is very limited. This creates new logistical challenges, including transportation to site, assembly of the crane, and mobilising the ballast.

Crane capacities will vary depending on the activities to perform at quay. The assembly of a turbine will require cranes to lift around 600 – 1,200 tons for a 10-15 MW turbine to sit the rotor-nacelle structure on top of the floater. Depending on the geometry and location of the turbine, cranes will also require enough mobility to reach the hub height of 150m approximately (additional to the floater height), especially when the turbine is located in the centre. Larger cranes could also be used as a load-out method, in which case they would be able to lift the weight of the foundation after assembly additional to the turbine weigh. Lighter structures could use cranes, such as TLP and semi-sub.

Re-purpose of jack-up vessels at the quay side could also be a solution, because this would make it possible to gain the hook height required. However, given the current demand for vessels not only in

Europe but in other markets, more vessels will need to be deployed. In addition to the heavy lifting requirements, the larger cranes, turbines and foundations have changed the requirements of the carrying capacity. The pre-assembly port storage area must accommodate a minimum overall surcharge load of 15 t/m^2 as a uniform distributed load (UDL) and 12-16 ha for 10 MW wind turbines. Areas determined for heavy lifting crane operations must accommodate a minimum surcharge load of 30-40 t/m^2 (UDL) which increases to a maximum surcharge of 50-80 t/m^2 (CL) by operation of the main crawler crane on a single track to the load spreading surface[2].

[2] Carrying capacity requirements are based upon single crane operations with no additional crane operating within a centre distance of 25m. Full load crane operations must be permitted down to 3 - 5m from the quay wall face.

Port La Nouvelle: The Port of the Energy Transition

Figure 12. Port of Ports La Nouvelle – Vision to 2021 (Copyrights : Agence Adocc, 2020)

The Port La Nouvelle is located in southern France and conveniently reaches the Mediterranean markets, being the third largest port on this sea basin.

Today, the Port is specialized in dry bulk and grains, cereals and refined products shipping. Beyond the ongoing expansion of the port to accommodate larger ocean-going vessels of 14.5 m draught, the Region Occitanie is aiming to make it as the port of the Energy Transition. Specific infrastructures to welcome floating offshore wind, other renewable energy source and hydrogen are being built. This will include a dedicated heavy quay and dedicated areas for the, the assembly, the deployment and the operation of floating offshore wind turbines.

There have been over €230 million of investments in new infrastructures to support the development of floating offshore wind in the Mediterranean. This includes:

- Reinforced quay of 200 x 50 m;
- A specific area with a capacity of 30 t/m^2;
- 10 ha with strengthen soil.

The port is already working with EolMed windfarm and EFGL – Eoliennes Flottantes du Golfe Du Lion - for the two pilot projects of 28-30 MW which will come online in 2021/2022 and is already looking into the development of the commercial phase confirmed by the French Government.

3.4 INSTALLATION

In bottom-fixed wind farms, foundations are installed before final installation of turbine topsides. It is this final activity that is most sensitive to sea and wind conditions and hence typically is carried out between April and October. However, some developers have managed to extend this time window. Prior to the installation, the project developer will gather the foundations, towers, blades and nacelles at the port close to the wind farm. Due to the large number and size of turbine parts, large areas of open storage and pre-assembly space are required. Because of the weight, a high carrying capacity quay is also necessary with up to 50 t/m^2 for concentrated load. Sea weather conditions will affect most of the towing activities due to speed limitations and significant wave height allowed to safely transport the turbines mounted on the floaters to offshore location.

Different types of vessels are required for construction of offshore wind farms, including vessels for inspection, cable laying, securing with rocks, wind turbine installation vessels (jack-up vessels), components mobilisation (Roll-on-Roll-off vessels), service operating vessel (SOV), and Crew Transfer Vessels (CTV). Some vessels might be able to complete different tasks from the above. This becomes more relevant in the case of large distances. As the vessels costs for developer can be very high (in the range of 130,000 to 150,000 €/day for jack-up vessels), efficient supply chain and logistics are an important requirement.

Ports would need to increase their capacity to build and service at least 500 MW/year of FOW projects in this decade and 4 to 7 GW/year from 2030 onward to reach the decarbonisation targets. All the floating platforms currently in operation – barge, semi-sub, spar – have performed installation of the integrated floater-turbine system using various towing vessels. The main installation challenges will be related to the load-out of the integrated structure into the water (in case assembly takes place in the same port), the weather which together with the distance from shore limits the wet tow installation period and the quay draught, especially when a larger draught is needed. Depending in the installation process some floaters could require specific operations like upending of the structure for spar and tension tensioning in TLPs.

Port of Amsterdam: Offshore Wind Hub

Figure 13. Vision for Offshore Wind Hub in Amsterdam, Netherlands (Courtesy of Port of Amsterdam)

Port of Amsterdam's strategic expansion: strengthening two Seaports

At the location of the former Averijhaven, Port of Amsterdam, as part of a consortium that includes five regional partners (public and private and national government) is developing an energy port that will include hubs for storage and logistics poles. The site will be tailored to offshore wind installation and larger maintenance campaigns and foresees other activities in future, to support the energy transition.

Specifications requirement to meet future offshore wind activities include:

- 15ha of available space
- 200m offshore equipped quayside available
- 380m quayside in total
- 12.5m draught (LAT)

Both port authorities of Port of Amsterdam jointly and Port of IJmuiden will take up the commercial operation of the site. The Ministry of Infrastructure and Water Management will contribute €27 to the development of the Energyhaven. The Port will be ready for construction and installation for Hollandse Kust West (2024) and for UK installations from Offshore wind leasing Round 4 (expected 2025 onwards). It will also support larger maintenance campaigns.

This is part of a regional vision on offshore wind, combining strengths in a multiple site strategy. In this vision, Energiehaven will provide space for installation, while Port of IJmuiden facilitates O&M and installation support and Port of Amsterdam provides for cable logistics and investments for component manufacturing sites.

3.5 OPERATION & MAINTENANCE

The maintenance of the wind farm is usually carried out from a nearby port using Service Operation Vessels (SOVs). These ports house the maintenance crew and vessels needed to respond to wind farm faults, plus storage and repair facilities. As wind farms become larger and further out in the sea (up to 100km from shore), the use of helicopters and offshore accommodation vessels/platforms are already used.

O&M activities can be classified into preventive and small corrective maintenance and heavy maintenance (i.e. large parts replacement). This will impact the infrastructure requirements needed to perform these activities.

Quick Reaction Ports are intended to be the homeport for operations and maintenance vessels. The ports must be close enough to the wind farm to allow vessels to reach the site in less than two hours. These ports mostly offer services as crew transfer, minor maintenance and repairs and they can be homeport for pre-installation work (e.g. resource assessment).

Weather conditions can limit the O&M activities. The use of helicopters decreases the impact of harsh weather conditions, particularly high waves, and results thus in an increased available period for O&M and increased safety and security.

Most floating platforms allow for large repairments at ports, towing the floating turbines back to the port using a dry-dock or in the quay. Some studies are currently evaluating which approach is less costly. Results will also differ across platforms and projects characteristics such as distance to port (BOEM 2016).

In the case of semi-sub and barge, it might be cheaper to hook-off and tow back to port. In the case of spars and TLPs, both onshore and offshore repairs are also possible, but depend largely on the design of the mooring system and the ability to stabilise the motion of both the structure and the vessel while performing repairs. In all cases, the cable and mooring are key for in the floater design to have a quick-release system allowing to connect and disconnect the unit.

Oostende – REBO: Operation and Maintenance port

Figure 14. Tower Assembly in Renewable Energy Base of Oostende (REBO), Belgium (Courtesy of REBO)

The Renewable Energy Base of Oostende (REBO) is a multi-purpose port, which offers handling, lifting, storage, assembling and transportation of offshore components. It offers a maritime access harbour of 270m with no lock or bridges and priority for installation vessels. The warehouse space for storage is 50,000–80,000m^{2}, with an additional 90 ha storage for breakbulk activities within the inner and outer port.

REBO offers O&M services for Nobelwind, Belwind and C-Power I, II and III (all bottom-fixed). These wind farms have been also built from REBO terminal. In 2018 it mobilized 4,568 Crew Transfer Vessels (CTVs) trips as well as 96 Service Operation Vessels (SOVs) trips. It offers services of preventive and corrective O&M and by end of 2020 will be serving around 400 wind turbines. The terminal also offers offices and storage areas where currently MHI Vestas, SGRE, DEME offshore have a fully equipped sanitary complex for up to 100 technicians. It also offers training and education facilities at the RelyOn Nutec Center. New warehouses and offices are currently under development.

The following table shows an overview of manufacturing, assembly and installation activities for the four types of floating foundations. The table has been adopted from (The Carbon Trust 2018) and complemented with other sources (BOEM 2016) ((FEE) 2019) and views from industry experts.

Table 3. **Overview of manufacturing, assembly and installation activities for each type of floating foundations (Slatte and Ebbesen 2012) (The Carbon Trust 2018) (BOEM 2016)**

Key Feature		Barge	Semi Sub	Spar	TLP
Substructure material	Steel		●	●	●
	Concrete	●			
	Hybrid	●	●	●	●
Substructure fabrication	Onshore	●	●	●	●
	Dry Dock[3]	●	●	●	●
Substructure assembly	Quay[4] with crane	●	●	●	●
	Dry Dock	●	●	●	●
Turbine Assembly	Pre-assembled rotor	●	●	●	●
Lower tower integration	Onshore	●	●	●	●
	Quay	●		●	
Turbine integration	Onshore	●	●	●	●
	Quay	●	●	●	●
	Offshore		●	●	●
Substructure loadout	Crane	●	●		●
	SPMT Trailer[5]	●	●	●	●
	Wet Dock	●	●	●	●
Transit	Crane barge[6]	●		●	
	Tugs[7]	●	●	●	●
	Special purpose vessels				●
Substructure-turbine integrated tow-out transit	Wet tow	●	●	●	●
Mooring System	Pre-installation	●	●	●	●
	Post-installation				●
	Taut configuration[8]	●	●	●	●
	Catenary configuration[9]	●	●	●	●
	Other configuration				●

[3] Enclosed area adjacent to port water for construction, loading, unloading and repairs of floaters and ships that can be flooded with water using a removable gate (wet dock).
[4] Structure adjacent to the shore of a harbour to carry load and unload of shipments and floaters.
[5] Self-propelled modular trailer used for transportive big or heavy components.
[6] Barge with crane attached for lifting heavy loads offshore.
[7] Small ships used to pull or push large floating objects for manoeuvring or salvage purpose.
[8] Mooring system with pre-tensioned lines with an angle between 30 and 40 degrees.
[9] Mooring system with free hanging lines horizontally at the seabed.

4. FUNDING AND POLICIES FOR FOW INFRASTRUCTURE

Floating offshore wind will contribute to reaching the decarbonisation targets providing almost a third (between 100-150 GW) of all the installed capacity by 2050 (BVG Associates for WindEurope 2019). This needs an industrialisation strategy in Europe.

Ports will need both public and private finance to accommodate for the rapid and necessary growth of the sector. Investments in the order of €0.5-€1bn in new port infrastructure for offshore wind could already help the offshore wind sector to cut costs by up to 5.3%[10].

4.1 FINANCIAL INSTRUMENTS

Due the infrastructure challenges and elevated costs associated to ports adaptation to the offshore sector, it is very important to ensure a very long-term revenue certainty for the exploitation of those facilities as part of the national energy policy. To ensure full industrialisation, governments should provide clarity, ambition, predictability and a visible steady pipeline of projects. Stable legislation would decrease investment risk, while technological consolidation will allow ports to strategically plan the expansion or adaptation of their facilities in the most efficient way. But policy on ports development is often locked away at the regional level since offshore activities compete with other industry activities that might provide higher returns in the short term (e.g. cargo logistic).

Policy makers should recognise the high societal value of investing in offshore-ready ports and make available financial instruments accordingly for ports and project developers. The EU Recovery Strategy will mobilise investments of €750bn in the Next Generation EU for the next four years. This is once in a lifetime opportunity for investing in ports infrastructure as key in the offshore wind supply chain and to support a just transition in regions transitioning from fossil fuels to renewable sources.

This together with policies should focus on bringing technology to maturity through investing in R&I while ensuring a long-term development strategy.

- **Grants** remain a vital tool to preparing port facilities for offshore wind development, ensuring a viable business case based on a longer return of investments. The EU Recovery Plan should target port infrastructure for offshore wind (bottom-fixed and floating) supporting the energy transition.
- **Loans** are equally important as they provide attractive pricing and a signalling effect, helping the project attract the necessary capital for such large investments. The EIB will need to play a crucial role to reduce investment risks and leverage finance from commercial banks.

[10] Up to 5.3% of direct and indirect LCOE reduction for offshore wind by 2030 (WindEurope 2018)

- **Financing offshore floating projects** must be supported with long-term investment mechanisms such as Contracts for Difference to keep financing costs as low as possible.

4.2 NATIONAL POLICIES

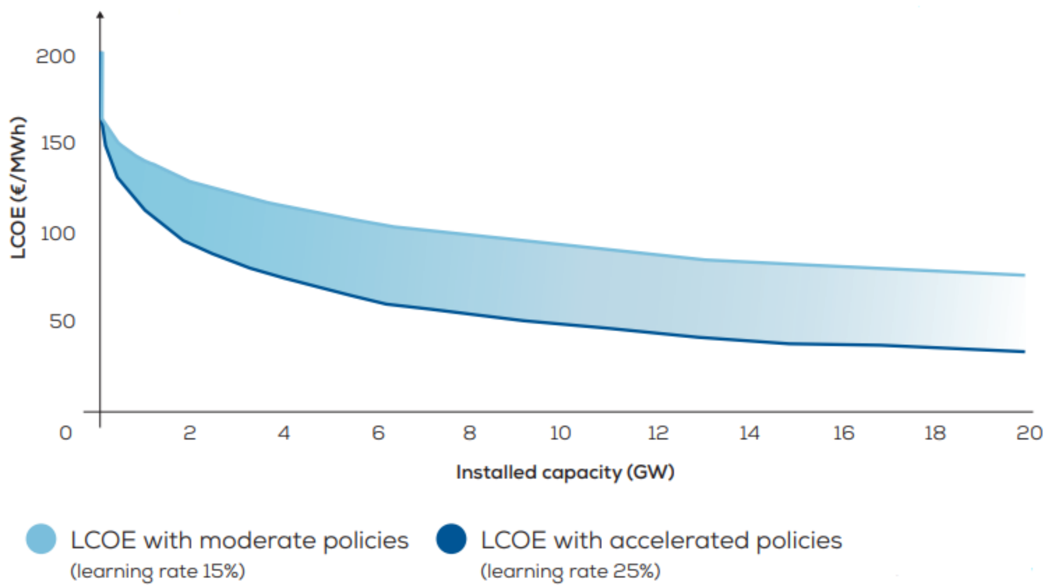
Only a limited number of European countries today are planning technology-specific auctions for floating wind. More countries should replicate this and at a larger scale.

France will launch in 2021 the first 250 MW auction and in 2022 it will host two auctions of 250 MW each. The auctions have a target price of 120 €/MWh and 110 €/MWh respectively. The results of these auctions will determine the conditions for the next auctions from 2024 onwards.

Scotland is moving towards allowing floating wind technologies as part of the coming auctions. The current Scottish Government offshore wind policy statement includes grant funding for innovation, enabling demonstration of technologies to reduce the cost of bottom-fixed and floating offshore wind (Directorate 2019). And it is expecting to receive applications in the ScotWind lease for both bottom-fixed and floating foundations.

The UK is considering amendments to the current Contracts for Difference (CfDs) scheme for the next round. Floating offshore wind might qualify for a separate pot in emerging technologies at their own strike price.

Figure 15. LCOE reduction projection (ETIP Wind Executive Committee 2020)



The European Technology & Innovation Platform on Wind Energy (ETIP Wind) has estimated the difference in the cost projection reduction for floating wind with moderate and accelerated policies (figure 15). The next decade will be crucial for the industrialisation of FOW, in Europe and globally. Europe will need at least 5 GW/year of FOW allocated and consented from 2025 onwards if it's to get 100-150 GW by 2050.

The policy framework and port infrastructure upgrades for developing floating offshore wind in Europe should target:

- There will not be a single "one size fits all" solution. The first step to industrialisation is to identify and select the best designs for each environment and market to kick-off serial production of floaters (50-100 units/year).
- Incentivise technology-specific auctions for floating technology with long-term revenue stabilisation – such as Contracts for Difference at their own strike price.
- Earmark support for an EU-wide fund to develop projects and supply chain at regional level across several Member States.
- Develop a clear strategy of ports to allow perform all various harbour activities (manufacture, assembly, installation and O&M) at regional level while maximising the whole supply chain efficiency of offshore wind.
- R&D could be best used to fine-tuning certain components, like optimising and adapting dynamic cables, mooring systems and other auxiliary services for mass scale production.
- Dedicate funds to support coastal areas and regions upgrading their port infrastructure to facilitate development of floating offshore wind (crane, space, draught, surcharge load and quay draught).
- Support joint projects between industry and research institutes to test the feasibility of different floating specific solutions (load-out methods and onshore vs offshore O&M).

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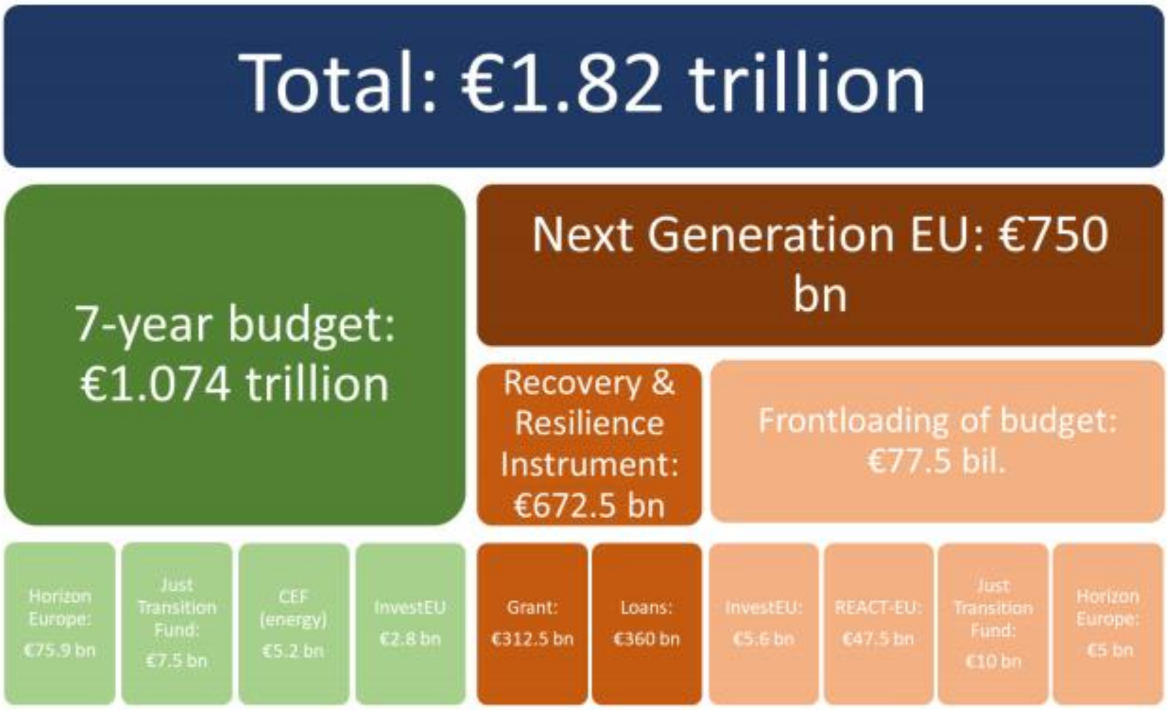
ANNEX I. FUNDING OPPORTUNITIES

The European Council reached agreement on a recovery plan to counter the economic impacts of COVID-19. The total recovery package amounts to €1.82 trillion. It combines a new, €1.074 trillion proposal for the EU's seven-year budget for 2021 to 2027. And an unprecedented recovery fund – Next Generation EU – worth €750 bn. The figure below shows the budget structure.

Figure 16. EU Recovery Strategy budget ((WindEurope 2020)[11])



The major funding programmes and publicly backed finance that could support projects in port infrastructure upgrade include.

The **Recovery & Resilience Facility** with a total €672.5 bn will allow Member States to submit proposals to invest in projects that are in line and will accelerate the delivery of their 2030 National Energy & Climate Plans. €312.5 bn of this package will take the form of grants and the remaining €360 bn the form of loans. Physical infrastructure could play an important role in this programme, this includes the upgrades needed for the wind supply chain.

The **Just Transition Fund** will support EU member states and regions most affected to a low carbon economy with a total €17.5 bn. All Member States are eligible for funding, based on the just transition

[11] EU Recovery Strategy: analysis and key asks. WindEurope (2020). *Available for members only.*

territorial plane, done in conjunction with the territorial authorities. This instrument will support the first renewable projects in coal transition regions which require also the right infrastructure.

Horizon Europe (previously Horizon 2020) is the biggest EU Research and Innovation programme with nearly €75.9 bn of funding available over 7 years (2021 to 2027) and €5 bn under Next Generation EU expected mainly in the form of grants. Its aims to support the incremental improvements in more mature technologies. For ports, specifically, it focuses on making equipment and systems for vessels smarter, more automated, cleaner and quieter while reducing the use of fossil fuels and finding smart infrastructure solutions to deploy innovative traffic management and information systems, advanced traveller services, efficient logistics, construction and maintenance technologies. It could involve ports by targeting industrialisation of manufacture and installation activities for FOW.

The **Connecting Europe Facility (CEF)** for Transport and Energy budgets support infrastructure investment at European level. It supports the development of high performing, sustainable and efficiently interconnected trans-European networks in the fields of transport and energy.[12] CEF offers financial support to projects through grants and innovative financial instruments such as guarantees and project bonds. These instruments create significant leverage in their use of EU budget and act as a catalyst to attract further funding from the private sector and other public sector actors.

The **European Maritime and Fisheries Fund (EMFF)** is one of the five European Structural and Investment Funds which complement each other to deliver more jobs and growth in the EU. It had an overall budget of €6.4 billion for the period 2014-2020. The objective of the EMFF is to support two main policy areas: the Integrated Maritime Policy (IMP) and the Common Fisheries Policy (CFP). The fund had made available €292 million (4.5% of this budget) for integrated maritime policy and the blue economy. Offshore wind energy and ports can apply for funding under this area to support coastal communities in diversifying their economies.

The European Investment Bank (EIB) is the lending arm of the European Union. It focuses on four areas: innovation and skills, small businesses, infrastructure and climate and environment. Particularly for ports, the type of projects the EIB would finance are:

- Existing ports – common user infrastructure rehabilitation/expansion: breakwater, access channel, maritime locks, navigation aids and quays;
- Existing ports – new terminals: port authority/infrastructure and/or terminal operator/superstructure and equipment;
- New ports; and
- Improvement of hinterland transport connections, particularly rail and inland waterways access to ports and intermodal terminals.

[12] Connecting Europe Facility (European Commission 2020)