Co-designing opportunities towards the development of Irish offshore wind

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Summary:

This document highlights a number of key issues that face Ireland as it moves towards large scale offshore windfarm development. It provides an overview of challenges and provides recommendations on potential future strategies for Ireland. The report focuses on *Environmental Conditions, Irish Ports* and *Supply Chain and Expertise.* It addresses specific issues relevant to Ireland across the lifecycle process of an offshore windfarm including: installation; operation and maintenance; and decommissioning.

The *Environmental Conditions* section points to the energetic nature of Irelands offshore waters and the opportunities and challenges that presents. The *Ports* section highlights the current lack of port capacity in Ireland particularly for installation purposes and that initial offshore windfarms in Ireland are likely to be developed from non-Irish ports. The *Supply Chain and Expertise* section indicates that Ireland currently has a limited but very expert supply chain that has the potential for significant growth as the industry develops.

An overall recommendation is that stronger commitment from government is necessary to enable the development of a pipeline of projects, prove bankability and instill confidence into the industry such that to encourage private investment.

Definitions

H_S	Significant wave height
CTV	Crew Transfer Vessel
HLV	Heavy Lift Vessel
LAO	Vessel overall length
JUV	Jack-up Vessel

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1. Introduction and Background

1.1. Project Description

Eirwind is a MaREI Centre's industry-led collaborative research project, co-designing the opportunity around the sustainable development of Ireland's marine resources, using offshore wind as the catalyst for innovation and impact. The project is a collaborative initiative with ten industry partners to help accelerate opportunities towards the development of offshore wind in Ireland. The objective of the Eirwind project is to facilitate and enable decision-making by industry partners.

This document has been assembled as part of work package 3, *Development optimisation for Cost Reduction*. It aims to highlight the key issues that face Ireland as it develops a successful offshore wind industry. This report focuses on the issues involved in the supply chain and across the lifecycle process of an offshore windfarm including: installation; operation and maintenance; and decommissioning. This report will not go into significant detail, as each topic is significant in its own right, but it will provide an overview of the problems to be faced and advise recommendations for Ireland on its path towards developing an offshore wind industry.

At present, two critical barriers in its development of offshore wind in Ireland are permit and licensing and connection to grid. As these two barriers are examined in WP4 and WP5 respectively, they will not be discussed within this report.

1.2. Wind Energy in Ireland

Wind energy generated 22.8%[1] of Irelands electricity demand in 2017 making it the second greatest source of energy following natural gas. The vast majority of this energy is generated from onshore wind farms, the success of which has reduced the requirement for offshore wind which, until recently, was deemed to be half as expensive as offshore. In 2014, ECOFYS (2014)[2] determined the LCOE for onshore wind to be €60 - €100/MWh in comparison to €100 - €175/MWh for offshore wind. However, the costs of offshore wind have fallen in recent years obtaining strike prices of €63.31/MWh in the latest CfD auctions; outperforming expectations that offshore wind would reach €124/MWh by 2020[3]. If the price of offshore wind continues to fall in this manner it will be the cheapest form of energy available to market. In 2016 the wind industry (onshore and offshore) proved that it can significantly contribute to the global climate change solution as it overtook coal as the 2nd largest form of power generation capacity (Figure 1) consisting of 17% of Europe's installed total. The signals are thus very positive for the growth of the offshore wind industry in Ireland, which has been constrained by the lack of government support mechanisms and available grid connection[1]. However, challenges still face the industry as it attempts to lower its costs as it is not expected that initial large scale developments in Ireland will achieve the same LCoE values as some equivalent European farms.

Ireland has one of the best offshore wind resources in Europe, but only a single wind farm currently in operation (Table 1 and Figure 2). Arklow Bank Phase 1 has an installed capacity of 25.2 MW and was commissioning in 2004 without any governmental support mechanisms. It's located approximately 10km off the east coast of Ireland on a shallow sandbank. The installation process was conducted out of Rosslare port and utilised European skills, through Danish offshore wind company A2SEA. It was the first offshore wind farm to utilise turbines over 3MW, with seven 3.6 MW GE turbines installed on monopile foundations. Operations and maintenance are run from Arklow port.

[1] This report focusses on the development issues regarding the lifecycle processes of offshore wind farms in Ireland and therefore, neither government support mechanisms nor grid connection will be discussed in depth. These two barriers will be tackled in WP4 and WP5 respectively.

In 2018 the Renewable Electricity Support Scheme (RESS)[4] was introduced and this addresses a major issue related to the development of offshore wind in Ireland. The first auction is due in 2019, primarily for onshore wind but the second RESS auction, scheduled for 2020, has a single technology cap to allow for the inclusion of more expensive energy sources such as offshore wind. This should provide confidence and bankability for the six offshore wind farms located on the east coast of Ireland that are applying for consent.

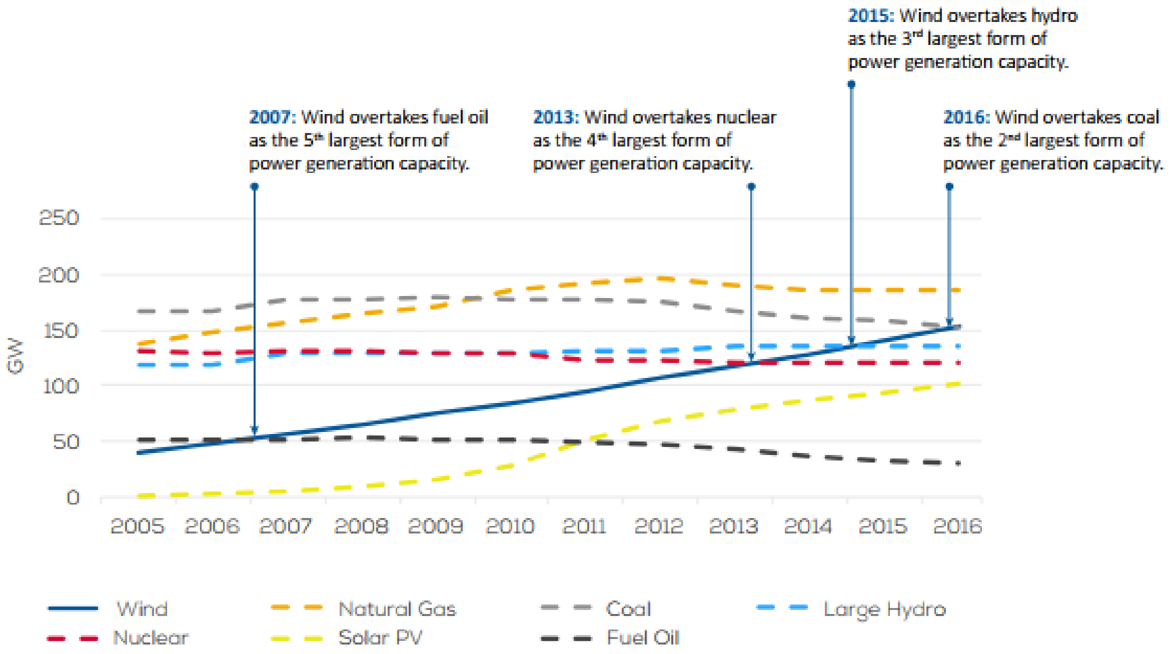

Figure 1: Cumulative power capacity of wind power (onshore and offshore combined) in the EU 2005 - 2016 [Source: Wind Europe [5]]

Name	Status	Size	Map Ref.
Arklow Bank Phase 1	Fully Commissioned	25.2 MW	8
Arklow Bank Phase 2	Consent Authorised	494.8 MW	8
Codling Wind Park	Consent Authorised	1,100 MW	6
Codling Wind Park Extension	Consent Application	1,000 MW	7
Dublin Array	Consent Application	340 – 600 MW	5
Oriel Wind Farm	Consent Application	330 MW	1
Sceirde (Skerd) Rocks	Consent Application	100 MW	10
Clogher Head	Concept/Early Planning	500 MW	2
Kilmichael Point	Concept/Early Planning	500 MW	9
North Irish Sea Array	Concept/Early Planning	750 MW	3

Table 1: Offshore wind farms in Ireland [Source: 4Coffshore [6]]

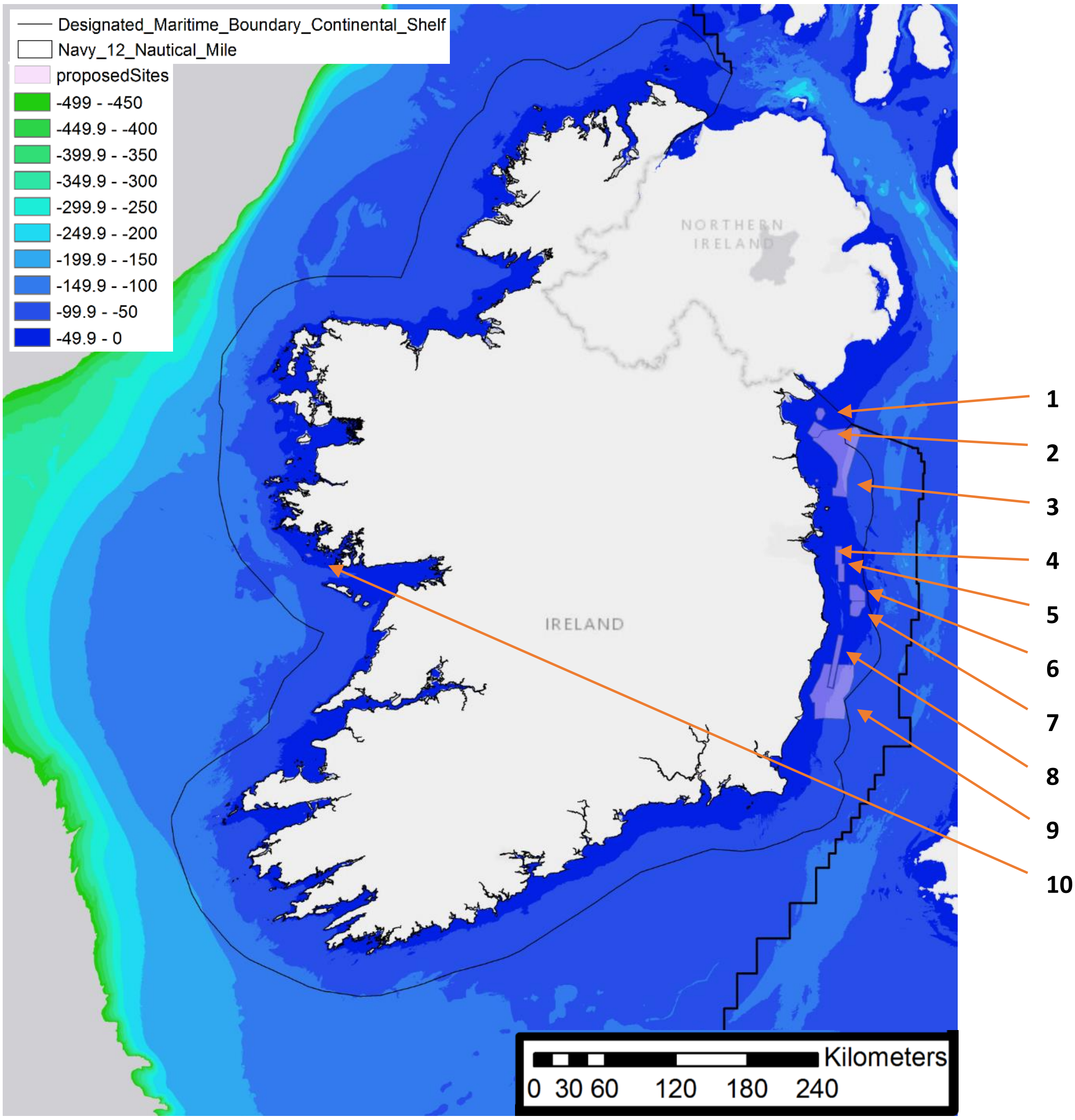

Figure 2: Map of operational, consented and planned offshore wind farms in Ireland Inc. bathymetry. [Source: 4Coffshore]

2. Environmental Conditions

Ireland has approximately 880,000 km^2 of economic exclusion zone (EEZ), much of which has potential for the development of offshore wind, however, not all of this is currently suited to the present day level of economically viable technology. To date 71% of the offshore wind farms in Europe are installed in the North Sea (Figure 3) due to its relatively good wind resource, manageable weather conditions, proximity to shore and shallow water depth[7]. This chapter will explore the environmental conditions that constrain Ireland in its development of offshore wind, but it will also highlight areas where Ireland can become European leaders in innovative technological development.

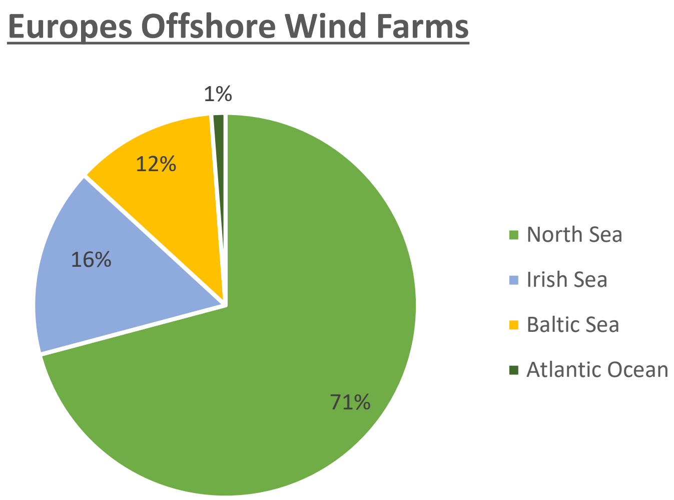

Figure 3: The division of Europe's offshore wind farms by sea region [Source: Wind Europe [7]

2.1. Water Depth

Water depth for offshore wind can be divided into three categories (*Table 2*). Each category of water depth has a different foundation technology that is the most viable associated with it.

Category	Depth	Technology Type
Shallow Water	<45m	Monopiles, XL monopiles, XXL monopiles gravity base foundations, jacket foundations
Transitional Water	45m – 70m	Gravity base foundations, jacket foundations, floating platforms
Deep water	80m +	Floating platforms

Table 2: Water depth categories

The Irish Sea is principally shallow to transitional water depths, with some areas reaching deep water closer to the territorial boundary with the UK. The shallow and transitional regions are able to take advantage of fixed bottom foundations, which currently consist of 99.5% of all offshore wind farms installed in Europe [7]. The most popular type of foundation, due to its simplicity of fabrication and experience in installation, the monopile (81.7% of European foundation types) is suitable for use within this region. To date, XL monopiles have been installed in waters up to 45m at Veja Mate offshore wind farm in the German North Sea [8].

The water depth in Ireland increases dramatically along the south and west coast of Ireland, reaching 80m within 20 – 80km from shore, and within 5 – 40km from shore respectively. These water depths are most suited for the use of floating platforms, or for innovative new fixed technology which is not yet on the market (i.e. Green Entrans). The use of floating platforms in offshore wind is not yet fully commercial. Equinor have a 30MW floating wind farm, Hywind, located off the coast of Scotland consisting of 5 x 6MW turbines on spar platforms. Whilst Principle Power Inc. are in the process of having 6 x 8.4 MW turbines installed on their semi-submersible platforms in Kincardine, Scotland. The water depths and their distance to shore around Ireland are ideal for utilising floating foundations, and hence this provides opportunities for Ireland to be an early mover in the commercial roll out of this innovative new technology.

2.2. Metocean Conditions

Whilst the offshore wind industry will benefit from the consistently high wind speeds generated across the Atlantic Ocean, these in combination with the wave conditions can hinder the processes associated with the lifecycle of an offshore wind farm. In accordance to Health and Safety factors, most offshore activities are restricted to the conditions that they can work within. These weather limits vary depending on the activities that are being conducted, and the equipment and/or vessels that are being used (Table 3). Offshore operations require stringent logistical planning to identify viable weather windows in order to conduct activities.

Activity			**Average Metocean Conditions**	
			Hs (m)	Wind Speed (m/s)
Installation [7][8][11]	Jack-up Vessel	Jacking-up	1.8 m	15 m/s
		Operations	5.0 m	20 m/s
	Cable Laying		1.5 m	15 m/s
	Foundation		2.0 m	12 m/s
	Transition Piece		2.0 m	12 m/s
	Turbine		2.0 m	8 m/s
	Floating Crane		2.5 m	15 m/s
Turbine Access [12]	Boat landing at sea-level		1.5 m – 2.0 m	15 m/s
	Platform at transition piece (SOV)		3.0 m	17 m/s
	Helideck		N/A	20 m/s

Table 3: Example of weather limits for certain key offshore activities and vessels

The Northeast Atlantic has one of the greatest wave climates in the world, generated by surface winds that produce large swells which can propagate across the Atlantic to first reach landfall on the western coast of Ireland. The west coast witnesses an average of 2.0m significant waves heights (Hs) in the summer and 4.0m Hs during the winter[13]. Whilst the Irish Sea has a more variable wave climate, it is mainly sheltered from large swells and has an annual average of 1.0m Hs. The south coast of Ireland like the west coast is dominated by Atlantic conditions, but is not as severe producing an annual H_S average of 2.0m. The wave climate around the coast of Ireland is mirrors by the wave producing wind climate. The west coast has the largest annual average wind speeds (13 m/s), generated by the low pressure systems that form in the North Atlantic, whilst the east coast of Ireland experiences the lowest annual wind speeds (7m/s) (Figure 8-Figure 10).

Metocean conditions play a vital part in the logistical planning of an offshore wind farm. All operations need to be undertaken within their weather limits to reduce risk, hence appropriate weather windows are required for the duration of the activity. During a wind farm's lifetime technicians are required, on average, to visit each turbine 15 times per year in order to conduct corrective and predetermined condition based maintenance work. Three methods of turbine access exist:

- Bump-and-jump utilising boat landings at sea-level;

- Walk-to-walk using hydraulic controlled Ampelmann devices;
- Helidecks.

Crew Transfer Vessels (CTV's)

Bump-and-jump methods are typically used by CTVs to provide a quick transfer method to the turbines, these however can only be conducted within 2.0 Hs. Consideration should also be given to the transit stability of the vessel. CTV's are required to return to port each day, and so technicians are susceptible to sea-sickness. This discomfort will therefore reduce their productivity whilst working on the turbine. Innovative CTV designs to tackle both turbine access and transport comfort are being developed, but these come with an increased cost. Small waterplane area twin hull (SWATH) and Surface effect ships (SES) are two vessels (Figure 4) which are beginning to be utilised as CTV's for offshore wind. They have improved stability that can provide safe access to turbines in up to 2.5m Hs and increased comfort. However, both come with higher costs.

Figure 4: Odjfell Wind's FOB SWATH vessel [14] *and ESNA's Sea Puffin* [15]*, a SES vessel, both utilised for offshore wind activities.*

The average annual Hs values illustrated in Figure 8 indicate that offshore wind farms to the west of Ireland and those outside the 12nm limit to the south of Ireland, would require SES or SWATH vessels to conduct turbine access. Whilst these locations are subject to calmer conditions in the summer months and harsher conditions in the winter months, significant logistical planning will be required to assess the economic balance between more expensive vessels that can work all year round, and less expensive vessels that are more restricted to the weather conditions.

However, by utilising Ireland's knowledge of the maritime environment and vessel use there may be an opportunity to develop innovative technology that can combat these harsh marine conditions. Furthermore, the importance of accurate logistical modelling that can optimise lifecycle processes could lead to the development of vital modelling tools.

Offshore Service Vessels (SOV's)

Walk-to-walk equipment is predominately utilised by SOV's to gain immediate access to a turbine at the transition piece 15-20m above the mean water level in up to 3.0m Hs (Figure 5). Motion compensated gangways are used to reduce relative movement on the structure between a floating vessel and a fixed wind turbine. The most common type of walk-to-work structure is the Ampelmann, which uses hydraulics to compensate for the motion of the vessel.

However, SOV's predominately remain offshore for a period of time rather than return to port as CTV's do, and hence are larger and more expensive. This added expense may be negated if the offshore wind farm is far from shore or in a harsh marine environment. The average Hs values illustrated in Figure 8 indicate that turbine access would be highly feasible for an Ampelmann equipped SOV's to the south and east of Ireland. However, challenges would still arise to the west of Ireland where 3.0m

Hs is reached at the 12nm boundary. Offshore wind farms in the west of Ireland would be required to face these challenges using logistical planning equipped with accurate marine forecasting capabilities.

Figure 5: Siemen's Estvagt SOV utilising an Ampelmann A-type walk-to-work gangway to access a turbine at the transition piece [Source: Ampelmann [16]*].*

Helidecks

Helicopters can be utilised for O&M and not restricted by the wave conditions (Figure 6). There are two methods of helicopter access to a turbine; first is a helideck. Offshore wind farms with fixed foundations would significantly benefit from the use of helicopters, however, they are only viable for activities that require a fast response because they are unable to carry large items of cargo. Furthermore, the use of helidecks on floating platforms installed off the coast of Ireland may still be dependent on wave conditions depending on the heave, sway and pitch response motion of platform.

Figure 6: Helicopter access to an offshore wind turbine [17].

Accessibility

Figure 7 illustrates the year round accessibility along the Irish coast in comparison to the North Sea utilising vessels with Hs access limits between 1m and 2.5m. Whilst the Irish Sea has comparable accessibility to the North Sea, the west (M1) and south west (M3) have significantly lower accessibility, and would require top of the range vessels to achieve 50% access.

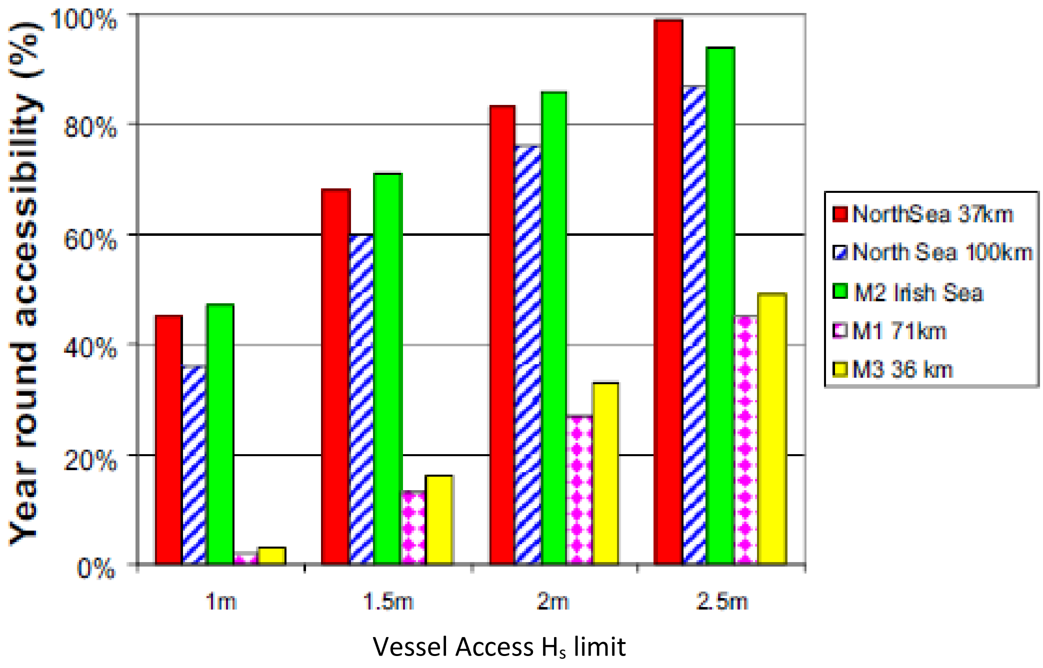

Figure 7: Comparison of year-round accessibility between two sites in the North Sea, M1 (Irish west coast), M2 (Irish Sea) and M3 (South West Coast) [Source: O'Connor et. al.[18]*}*

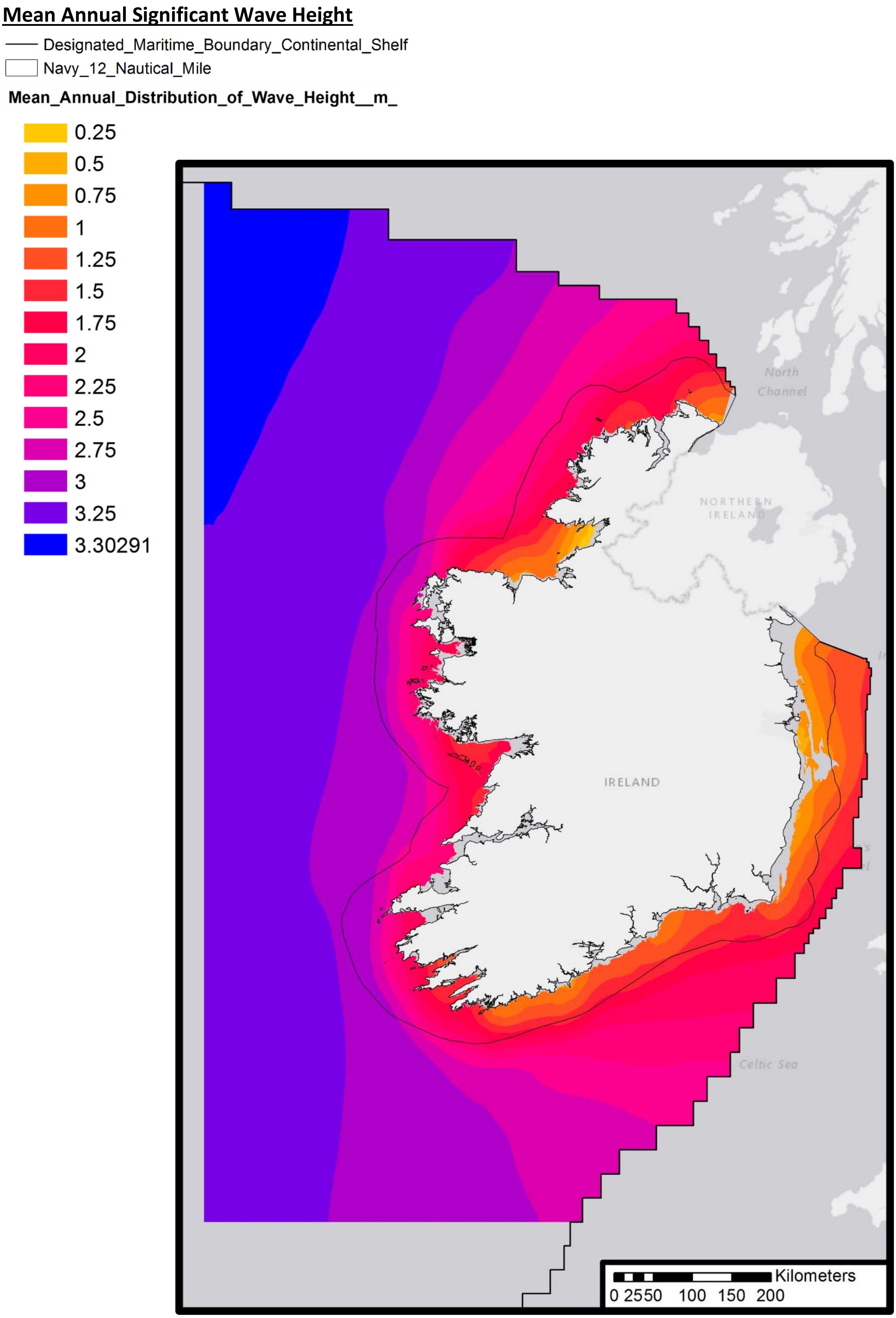

Figure 8: Mean annual significant wave height (m) around the coast of Ireland

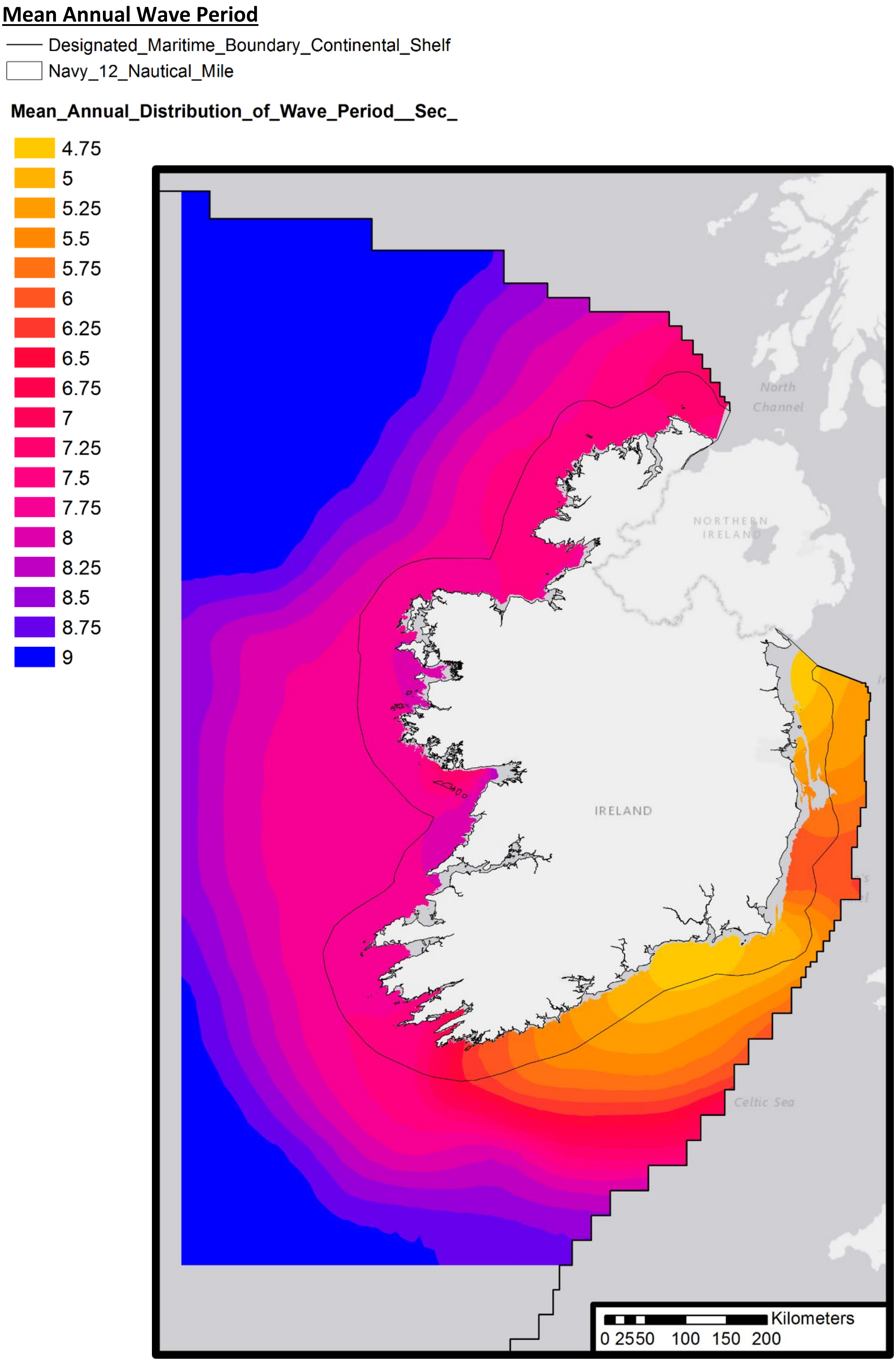

Figure 9: Mean Annual period (s) around the coast of Ireland

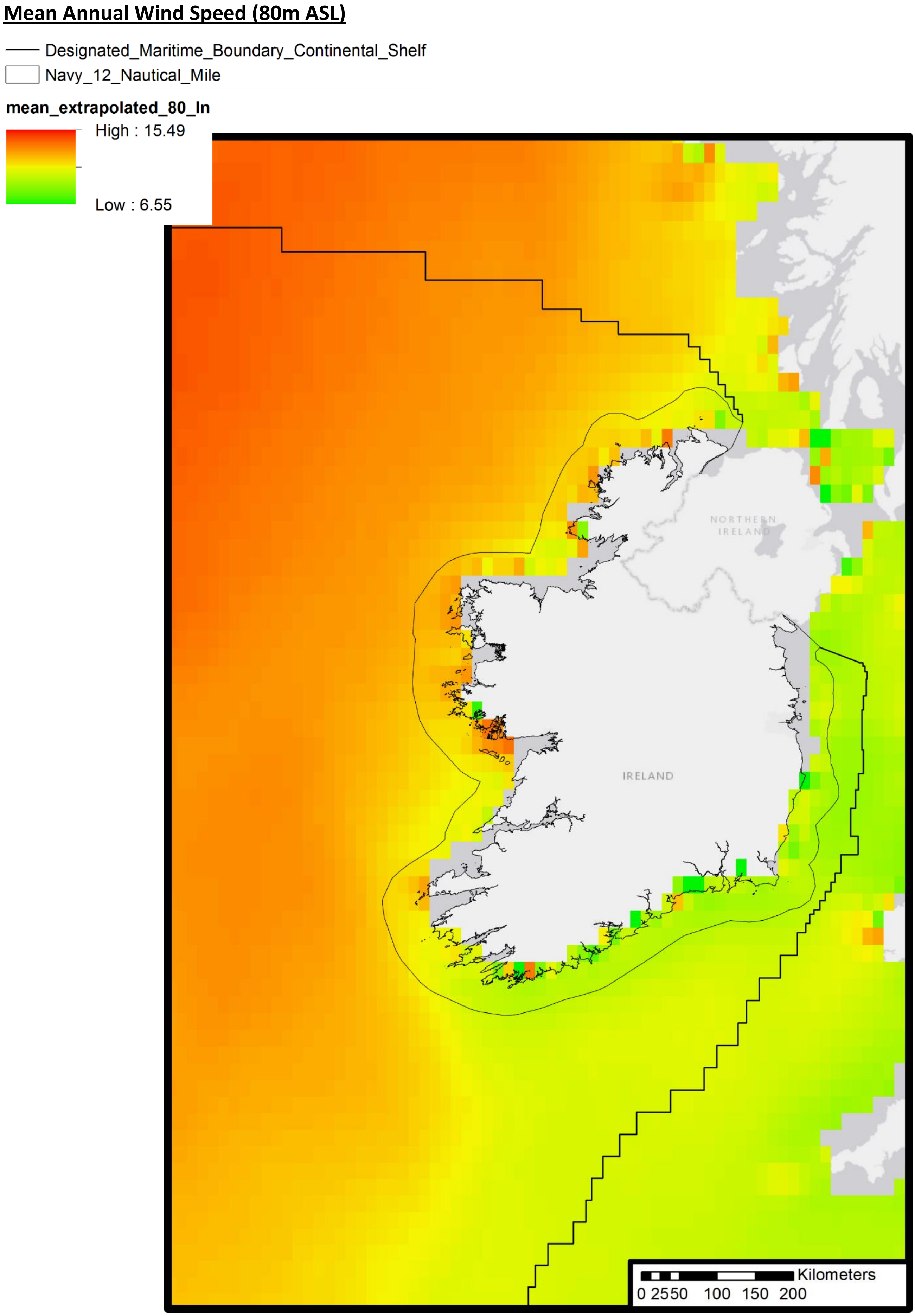

Figure 10: Mean annual wind speed (80m ASL) around the coast of Ireland.

2.3. Conclusion

Ireland's highly energetic ocean conditions are unique, providing an advantage to the offshore wind industry if the wind energy can be economically harnessed. The greatest challenges Ireland will face will be to utilise new innovative technology that is suited to its waters. This challenge encompasses developing foundations (fixed or floating) that are suited to its deep waters, and to the use of vessels with high enough weather limits to conduct offshore activities in Irelands harsh ocean conditions. It is highly likely that the offshore wind industry in Ireland will commence in the Irish Sea along the east coast, where the water depth is shallower and the metocean conditions are more benign. This will allow Ireland to develop the expertise required in the offshore wind industry before it advances into the more challenging conditions of the south and west coast. The north west coast of Ireland has the harshest metocean conditions, whereby most vessels would struggle to find appropriate weather windows to conduct offshore activities within health and safety limits. However, as the offshore wind industry grows in the rest of Europe, as do the size and weather limits of the vessels involved. Therefore, ultimately, this area may still provide potential for floating platforms in the future.

2.4. Recommendations

In summary, the following recommendations are made to the offshore wind industry in Ireland:

- Be conscious of the offshore conditions

Whilst these conditions are the main driver for developing offshore wind in Ireland, the harsh marine environment can inflict problems throughout the lifecycle processes of an offshore wind farm.

- Careful logistical planning of lifecycle processes

The implementation of careful logistical planning has the potential to reduce costs across the entire lifecycle of an offshore wind farm.

- Opportunity to become leaders in new innovative technology and methodologies

The harsh environmental conditions require innovative solutions, and Ireland has the opportunity to provide these. With research institutions focusing on the marine environment and local knowledge on the environmental conditions are beneficial and could ultimately lead to the exportation of skills and technology.

3. Irish Ports

Adequate port facilities are a vital requirement for the development of offshore wind. The need for a reliable and efficient ports which encompass all the necessary physical characteristics to support the offshore wind activity is critical, and furthermore, they have the capacity to reduce overall costs. WindEurope's Ports Platform (2018)[19] has suggested that there is potential to reduce LCoE by a further 5.3% if further investment in European ports is made.

Port requirements are becoming even more relevant with the development of floating wind platforms, which require much deeper berths to support installation, O&M and decommissioning. The Floating Wind Joint Industry Project (JIP) by the Carbon Trust (2018)[20] determined that there are very few ports with characteristics suitable to support large scale floating wind. Moreover, it reiterates that infrastructure and logistics will be a large contributor to making floating wind cost competitive.

Ports play a significant part across the entire lifecycle of an offshore wind farm. Installation and decommissioning activities require large ports with the capability of handling large vessels and an extensive supply chain. Whereas; small ports can support daily operations and maintenance activities, with aid from larger ports for large scale repair works. At present, Ireland have no ports dedicated to any offshore wind activity, beyond the importation of components for terrestrial wind farms. This chapter will review what is required for a port to support offshore wind activities, and the potential of Irish ports to facilitate them.

3.1. Port Requirements

There are three critical requirements that enable a port to support offshore wind activities:

- Physical Characteristics
  - Includes berth availability, port length, port depth, seabed suitability, quay load bearing capacity
- Location
  - Regarding proximity to potential offshore wind farm locations, adequate infrastructure and supply chain.
- Port Layout
  - Includes storage availability, component fabrication ability.

It has been estimated that for Ireland to support 500 – 1,000 MW of offshore wind on the east coast, 2 dedicated berths/tenders would be required, 10 – 20 hectares of available quay land for component assembly and storage and an estimated workforce of 250 – 500.

Physical Characteristics

For a port to support offshore wind it is necessary for it to have the physical characteristics to accommodate large scale installation vessels and suitable quay space for the storage and loading of components.

Ports need to cater for large and expensive jack up vessels JUV) (Table 4) that typically conduct offshore installation procedures. Therefore, berths, locks and quays need to be able to accommodate vessels of this size with ease to prevent lengthy docking procedures. Furthermore; many jack-up vessels require specific seabed foundations with the capacity to withstand their loaded weight once jacked-up, so they can utilise onboard cranes required for loading. These beds are dependent on the design of the legs of the JUV: pointed legs are most suited to soft sediment, whilst flat legs are suited to stone beds. Hence, port logistics need to carefully consider the specifications of vessels required for the offshore operations and the suitability of their port infrastructure. Simulations are conducted prior to the arrival of new vessel to determine the best method to dock.

Vessel Name	Company	LAO	Breadth	Draft
Innovation	DEME	147.50 m	42.00 m	11.00 m
Sea Installer	DEME	132.41 m	39.00 m	5.80 m
Aeolus	Van Oord	139.40 m	44.46 m	8.60 m
Orion	DEME	216.50 m	49.00 m	16.80 m
Goliath	GeoSea	59.00 m	32.20 m	5.00 m
Brave Tern	Fred Olsen	132.00 m	39.00 m	9.00 m
Vole Au Vent	Jan de Nul	140.40 m	41.00 m	6.30 m
Scylla	Seajacks	139.00 m	50.00 m	11.00 m

Table 4: Physical characteristics of some offshore wind installation vessels

The depth of the port becomes more prominent when floating offshore wind is considered. Floating wind platforms are typically towed straight from port to their offshore site location, and so require enough port depth to accommodate the draft of the structure. This can range from 12m for a semi-submersible platform to 80m for a spar platform. Alternatively, if adequate port depth is not obtainable, auxiliary buoyancy aids can be used. However, this will contribute to added costs and increase complexity in the installation process.

The load bearing capacity of the quay side should also be considered. The land should have a suitably high hold capacity to withstand the lay down and loading of components. Quay side space directly adjacent to berths is essential for an efficient supply chain. This land should be reinforced to a specific degree to ensure it is capable of withstanding the loading associated with assembling components, loading components onto vessels and the required cranes.

Location

The location of the port is vital to ensure an efficient supply chain. The proximity to market is essential, as the transit time to offshore wind farms is a key component in its LCoE. Ports that currently support the offshore wind industry have a clearly defined roadmap of offshore wind farms in development. This is even more essential when considering that the installation procedure is a short-term consideration. O&M activities in comparison cover the entire 25-year lifecycle of an offshore wind farm. Since the two lifecycle processes require different port facilities it is important to highlight what would be the main function of that port.

Ports are also required to have good infrastructural links, via road, rail and maritime, to ensure that they can provide an efficient supply chain. Most of the large components will arrive at an installation port via vessel, however, smaller components may be manufactured inland and so high-quality road and rail links are necessary.

Port Layout

The implementation of efficient and effective port layout with improve the supply chain processes by minimising turnaround time [21]. Appropriate port layout can improve the efficiency of loading and offloading vessels (Figure 11), and reduce the amount of vessel waiting time, hence reducing costs. It is recommended to have two berths available to offshore wind vessels immediately adjacent to one another with suitable and adequate quayside available for the staging of components. This would allow one vessel to unload components whilst another is loading. Immediate access to the stage areas between the two procedures would also reduce complexity in transporting components. In 2012 it was suggested that 6.5 – 7.5 ha of available quayside land is sufficient prior to installation to

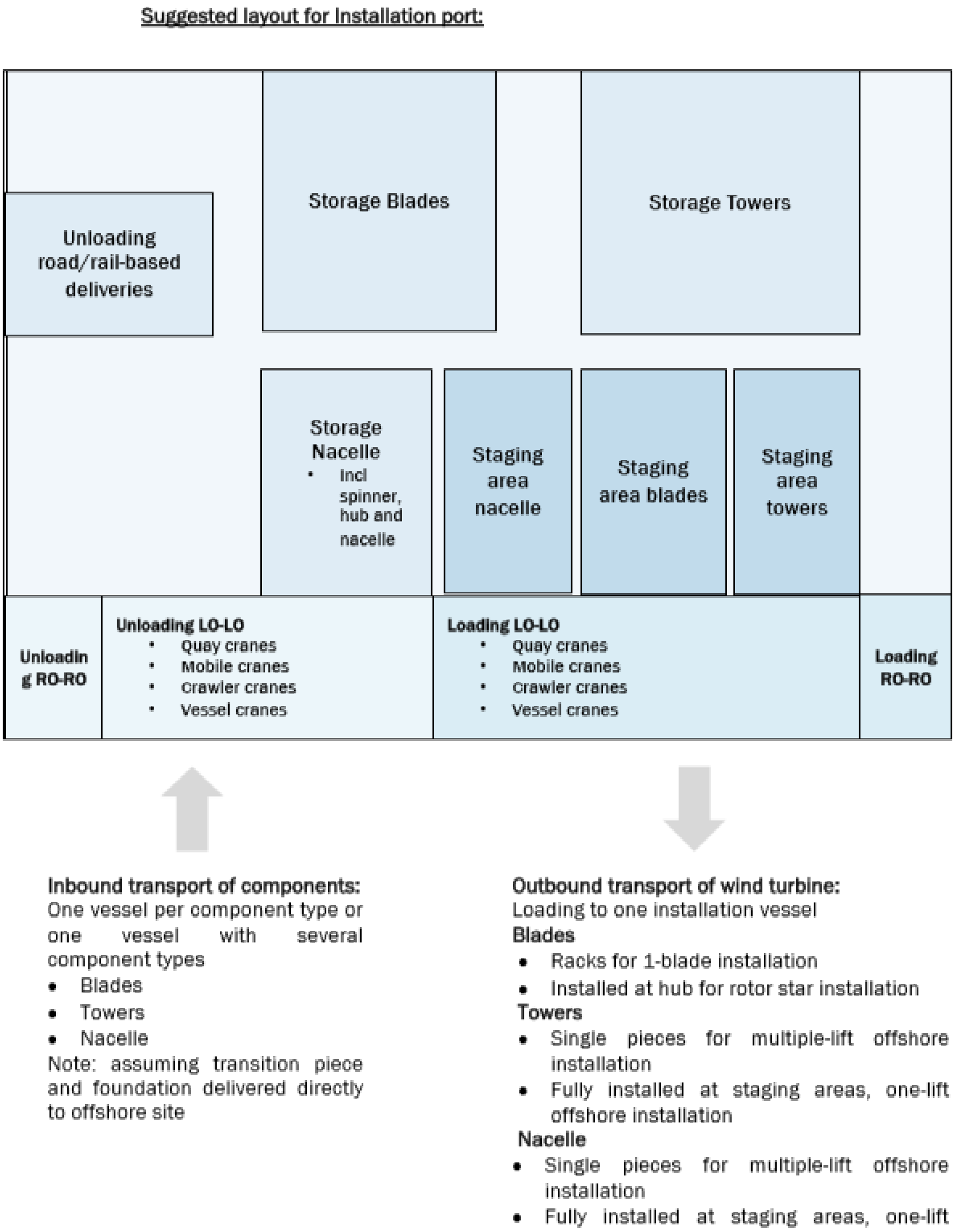

Figure 11: Example of a suggested layout for an installation port extracted from the LEANWIND deliverable 5.3 [21]

accommodate storage, loading procedures and assembly of components [22]. However, the size of turbines has increased from an average of 3.6 MW with a 120m rotor diameter in 14m water depth to 8 MW with a 164m rotor diameter in 25m water depth today. Therefore, the advised area of land required for efficient quayside activities should reflect this increase in component size.

The increasing size of offshore wind turbines and their substructures has led to the assembly of components at the quayside to reduce the complexity of their transport. Vestas have required 20 turbines to be fully assembled prior to the loading of vessels. This requirement prevents bottlenecks from occurring in the supply chain when weather windows are available for offshore processes to begin. This is especially important to note, due to the high charter rates of JUVs.

If a port has enough space it may be feasible to develop manufacturing facilities. Such facilities would reduce the complexity of the supply chain by enabling components to be directly loaded onto installation vessels. This would also develop an offshore wind terminal which could continue to act as a supply chain for offshore wind even in times of low installation activities in close proximity. A long project pipeline is required to encourage the development of a new manufacturing facility.

For further information on the importance of port characteristics, location and layout please refer to the LEANWIND Deliverable 5.3: Port suitability assessment for offshore wind development.

3.2. Case Studies

The first offshore wind farms installed in the UK did so from Port of Esbjerg in Denmark. However; over the past decade several ports across Europe have improved their facilities in order to accommodate offshore wind. These ports typical get support from either offshore wind developers or manufacturers of components to underwrite the cost of development. To gain the support of a developer, there must be a significant pipeline of proposed offshore wind farms in the region in order to provide long term prospects. Whereas, with the rapid increase in the size of turbine components, manufacturers prefer to have fabrication facilities close to port to simplify the supply chain whether installation activities are occurring from that port, or simply transport is required to another port for installation purposes. Therefore, it is a strategic decision between which development option is selected that best suits the characteristics, location and development potential of the port.

Belfast Harbour (Installation and pre-assembly port)

In 2012 Belfast Harbour invested £53 million to develop a greenfield site into a dedicated offshore wind terminal with the support of Ørsted A/S, an offshore wind developer. A heavy duty piled reinforced concrete relieving slab was installed to enable the pre-assembly and load-out of wind turbines onto installation vessels[23]. Further construction was required to upgrade the 50 acres of reclaimed land into storage area by installing heavy duty hinterland pavement comprised of unbound granular material reinforced with geogrids. The development of the port has been successful, proven by handling approximately 305,000 tonnes of wind farm components in 2017 [24].

D1 terminal at Belfast Harbour first supported the installation of West of Duddon Sands in 2013, located 100 nm from Belfast. Stone beds were constructed to enable the quayside to handle jacking-up capabilities of large installation vessels. Three vessel berths are available immediately adjacent to the turbine and foundation pre-assembly area (Figure 12-Figure 14). This allows for efficient transfer of components: with one berth available for incoming components and another berth available for the efficient loading of components onto the installation vessel.

The main port characteristics are as follows;

- 50 acres for Ørsted logistics and component assembly
- Heavy duty infrastructure (50 tonnes/m^2 loading capacity)
- 480m heavy duty quay
- 9.5m deep water channel
- 11.5m max berth depth

The port has been used as the pre-assembly site for 659 MW Walney Extension, and the pre-assembly and load-out port for 258 MW Burbo Bank Extension, both wind farms are located in the UK waters of the Irish Sea.

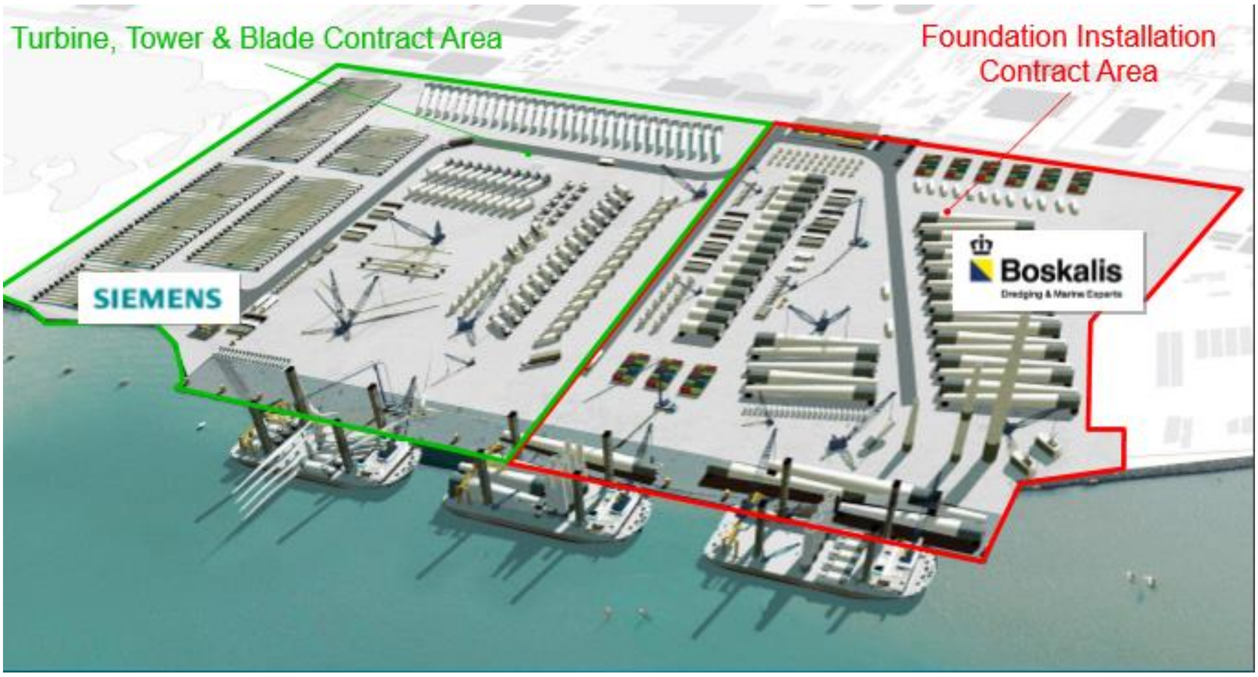

Figure 12: Installation layout for West of Duddon Sands [Source: Belfast Harbour [25]*]*

Figure 13: Belfast Offshore Wind Terminal Facilities [Source: Belfast Harbour [26]*]*

Figure 14: Belfast Harbour, D1 Terminal in action. Foreground: turbine towers. Right: Transition pieces. Background: Turbine Blades [Source: geography.ie [27]*]*

Green Port Hull (Installation and pre-assembly port)

When the economic crash reduced the demand for container terminals, Associated British Ports (ABP) took advantage of the rising interest in offshore wind and transformed their plans to develop Alexandra Dock into offshore wind terminal. ABP underwent an agreement with Siemens in 2014 to develop the port with an area dedicated to the manufacturing of turbine blades. A total of £310 million was invested into the development (ABP: £150 million / Siemens: £160 million).

ABP took notice of the importance of port facilities to the increasing growth of offshore wind when the Crown Estate zoned areas for development in 2008. However, finalising the contract between APB and Siemens relied heavily on the dedicated commitment to offshore wind provided by the UK government[28]. Green Port Hull was an ideal location for development due to its proximity to the North Sea and its planned pipeline of offshore wind farms; international infrastructure links; available quay space; prior experience in offshore activities; and local expertise and training centres[29]. There were initial worries about the availability of a workforce and the fear of stealing the workforce from other important local companies. However, there were ten times more applicants that available job positions.

Figure 15: Green Port Hull [Source: ABP [30]]

The development involved 7.5 hectares of land reclamation (now the blade storage and tower sites) and dredging to provide a deep water berth. This required 15.5m of dredging into clay, and the construction of stone beds to provide an adequate foundation for jack-up vessels. Green Port Hull was fully operational in 2017 after two years of construction. Siemens produced their first blades in 2016 and aim to produce 600 turbine blades per year. Alongside the blade factory, the port also accommodates a logistics and distribution facility, nacelle pre-assembly and associated offices [31] (Figure 15). Since its development Green Port Hull now accommodates:

- 40,000 m^2 wind turbine blade factory
- 8.3m quay depth
- 600m quay length
- Accommodates 152m maximum overall length for vessels (LAO)
- Assembly area adjacent to berths for easy access
- 3 berths (2 permanently available but with negotiations underway to lease berths during downtime)
- 54 hectares of available land for storage, assembly and warehouse activities.
- Created over 2,000 jobs (1,063 jobs created at the blade factory, and further 1,282 jobs in the local supply chain) [32]
- 12 hours sailing time to major Round 3 offshore wind farms.

Grimsby Royal Docks (Ørsted East Coast O&M Hub)

Ørsted are developing the Royal Docks at Grimsby Port as an O&M hub, immediately across the Humber Estuary to Green Port Hull, due to be fully operational in 2019. Grimsby already supports several offshore wind farms in the North Sea, including the 210 MW Westermost Rough and 270 MW Lincs, but the extension provided by Ørsted will turn the port into the largest offshore wind O&M hub in the UK. The site will host 350 employees and provide a base for the 1.2 GW Hornsea One and 860 MW Triton Knoll. A development in 2014 provided logistics and operations offices and warehouses to support offshore operations. The extension will include marine and helicopter coordination centre that will provide 24 hour support to offshore wind farms [33]. The base will provide berths for 2 large Østensjø Rederi SOVs that are capable of conducting 28 day deployments and are equipped with 23m walk-to-work gangways. The port also hosts Siemens, Centrica, E.On and RES.

Wick Harbour (O&M Base)

Located in the north east of Scotland, Wick Harbour presents the feasibility of small scale ports to provide O&M support and logistics to large scale offshore wind farms. Wick Harbour has been granted £15 million of investment to create an O&M base for Beatrice Offshore Wind Farm, including pontoons for six CTVs and the conversion of two historic buildings for offshore wind logistics and support. The development will create 65 jobs during its construction, and 90 jobs for long term operational roles across the 25 year lifecycle of the offshore wind farms in the region [34].

3.3. Port Feasibility in Ireland

Ireland has numerous ports distributed around its coastline (Figure 16). These ports range in size from small fishing harbours such as Castletownbere in the south to large scale commercial ports such as Rosslare Europort in the south east. Ireland has a heavy reliance on its port infrastructure to accommodate import and export in and out of Ireland, handling 53.3 million tonnes of goods in 2017. The ports predominately facilitate dry bulk (16,800 tonnes), roll-on/roll-off (15,500 tonnes) and liquid bulk (12,200 tonnes), with half of all goods handled by Dublin Port [35]. They also accommodate an annual average of 4.5 million passengers that utilise the maritime routes as transport in and out of the country.

Installation Ports

The installation and decommissioning processes are the most complex in the short term; requiring large JUVs and adequate quayside space to support the supply chain. The iPores report (2012)[36] reviewed all the Irish ports to determine their suitability and potential to support fixed bottom offshore wind and deduced that 3 ports (Cork, Shannon Foynes and Dublin) have immediate potential (Table 5).

Furthermore, the Carbon Trusts JIP [20] highlighted the need for adequate port facilities for floating wind. For ports to support floating wind, they require deeper water depths than those suited for fixed offshore wind farms. This is principally due to the installation process and O&M strategy. Floating platforms can have a draft of between 14m – 80m + depending on their design type (semi-submersibles and spar platforms respectively). Whilst it is possible to transport a floating platform from a port with a depth shallower than the platform's draft, it would require auxiliary buoyancy aids or debalasting, and their associated added cost and complexity. Hence, Ireland should take note of the Carbon Trust report and develop ports on the south and west coast, where water depth is greatest, to facilitate floating wind. This may include dredging work to deepen quaysides.

Port Name	Challenges and Potential for offshore wind	
Cork Harbour: Ringaskiddy Terminal	Pro's	• Good proximity to market potential on the south coast of Ireland. • Two ro-ro terminals of 180m/150m length and 9.2m/8.5m water depth to accommodate large HLVs. • Deepwater terminal with water depth of 13.4m – could accommodate the draft of semi-submersible platforms • Deepwater terminal has quay length of 485m – could accommodate length of spar platform transported horizontally. • Sheltered harbour with a channel reaching 24m water depth. Inner harbour bar at spit bank is dredged to 11.2 CD and can accommodate vessels up to 60,000 DWT and floating platforms towed by tugs. • Terminal area of 8.1 ha to act as quay side space for loading/unloading components from vessels • 16 ha of storage space behind berthage • Can accommodate lifts up to 1,000 tonnes • Experience in offshore oil and gas industry, turbine imports, ship building, vessel design, steel construction and fabrication and dry dock facilities. • Nearby research facilities at NMCI/Beaufort Building.
	Con's	• Shortage of available hinterland space. Whilst there is 16 ha of storage space and 8.1 ha of terminal space, theses spaces already have defined purposes. Planning would be required to deem whether the current purpose could be moved elsewhere. • Cork harbour requires a pipeline of projects and commitment before any development can be conducted. • Planning would be required to assess the feasibility of towing a 200m tall structure out of Cork harbour.
Shannon Foynes Port	Pro's	• Good proximity to market potential on the west and south coast of Ireland. • Experience in offshore oil and gas industry, marine renewables and turbine imports. • Two quays: 265m and 295m in length with 10.7m water depth that could accommodate both large JUVs and floating platforms. • Caters for vessels up to 40,000 DWT • Have strategic proposals in place and are ready to fully support the offshore renewable energy market.
	Con's	• The west coast of Ireland has the deepest water and the harshest marine conditions, and so it is likely to be the last place to along the Irish coast to develop its offshore wind potential.
Dublin Port	Pro's	• Good proximity to market potential on the east coast of Ireland. • South Deepwater suitable to accommodate floating platforms with 357m length quay and 11m water depth. • Alexandra Basin and Ocean Pier capable of accommodating HLV's with berths up to 410m in length and 10.3m water depth.
	Con's	• Has a no available space to accommodate offshore wind, including berth and hinterland space. • Very busy port which may not be able to support offshore wind - contributes to 46.9% of the goods handling and 60% of all vessel arrivals in Ireland.

Table 5: Potential for highest ranking ports to support offshore wind

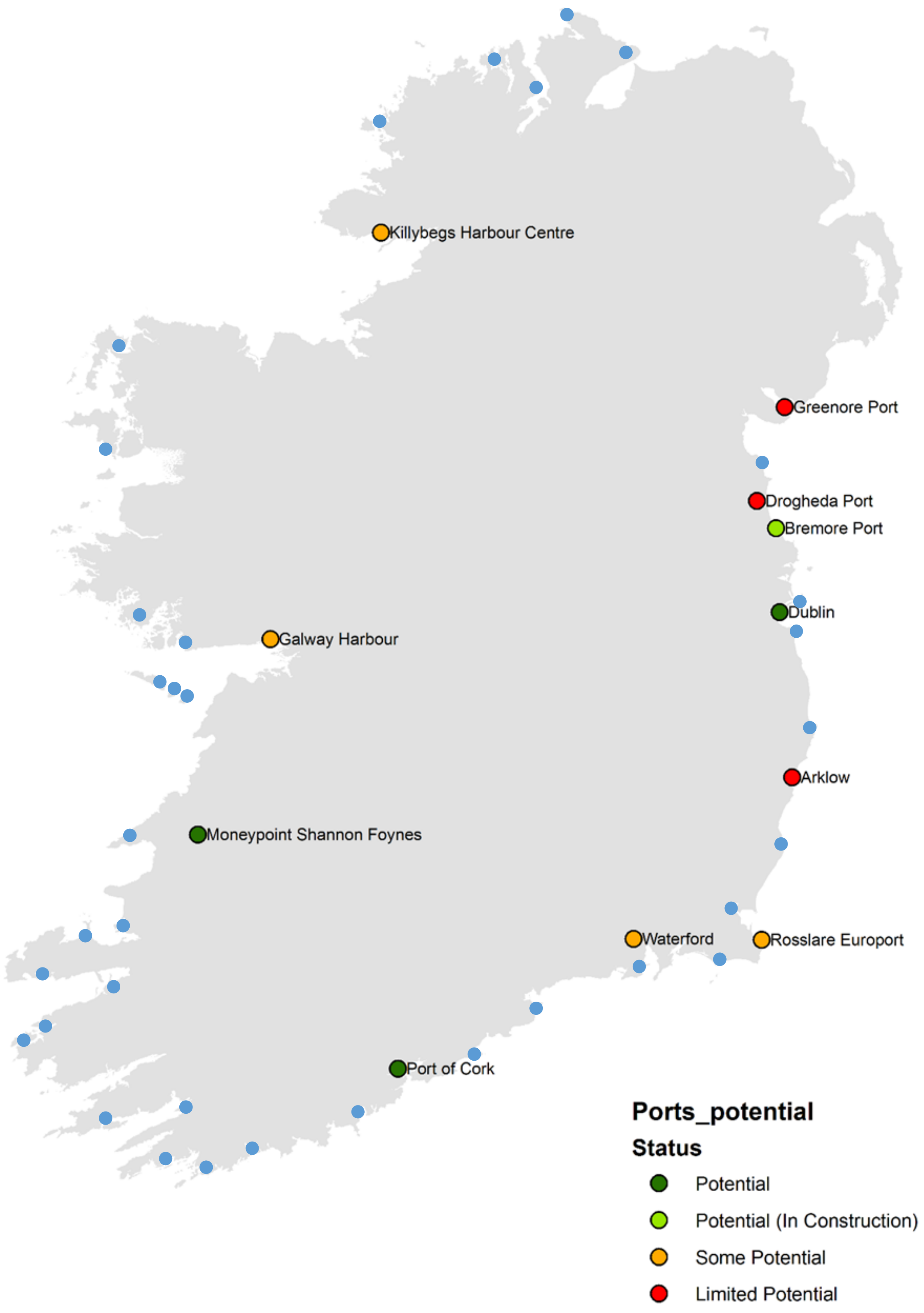

Figure 16: Map of the Ports in Ireland, with associated potential to host offshore wind activities. Blue dots represent small scale fishing harbours [36]

O&M Ports

Ireland's coastline has many small harbours that are dedicated to fisheries, marine tourism and leisure. Considering the size of Wick Harbour (Chapter 3.2), these smaller ports may be adequate to support the minor activities required in the O&M processes and provide employment opportunities for the region. Investment would be required to develop the appropriate pontoons for CTV's and construction work for logistics offshore space. However, this investment may be more beneficial for developers then having to conduct minor O&M work from ports a greater distance from the offshore wind farms, especially when considering weather windows required (Chapter 2.2). Major repair work may still need to be conducted from the larger ports that were used for installation activities due to the size of vessels.

3.4. Conclusion

Ireland do not necessarily need to have port facilities fully functional before the introduction of offshore wind. Installation and O&M of the first offshore wind farms, most likely to be positioned in the Irish Sea, can be conducted from UK ports which are already experienced at such activities. However, developments are required in the long term so that Ireland can be self-supporting of its offshore renewable energy resources. This is even more relevant considering that it is likely that floating wind will dominate the west coast of Ireland, and so western ports will need to be able to support the installation and O&M of floating platforms.

Cork and Shannon Foynes are two ports with high potential for supporting the large scale operations associated with offshore wind. Government support in the offshore wind industry is required to instil confidence into the sector and to promote investment in Ireland. Furthermore; valid licensing and permitting is also necessary (to be discussed in WP4). Without a viable pipeline of projects it is unlikely for any development to occur. However, once a specific offshore wind market is demonstrated, Ireland will be able to benefit from developer and manufacturer investment to develop its ports akin to Belfast and Port of Hull to accommodate the industry. The opportunity also exists to also provide testing facilities, training centres, warehouse offices and operational centres alongside development.

3.5. Recommendations

In summary, the following recommendations are made to the offshore wind industry in Ireland:

- Initial installation from ports outside of Ireland

Offshore wind in the Irish Sea can be installed from UK ports already familiar with the processes.

- Potential for agreements with developers/manufacturers

Akin to developments that have taken place in ports around Europe, including Port of Hull and Belfast Harbour. This will build on opportunities to develop O&M hubs, fabrication facilities and operations offices.

- Commitment from government

Government commitment is required to instil confidence into the industry and to develop the MSP to allow for offshore wind to develop. A pipeline of projects already exists and with suitable national incentives and investment developers can proceed and ports will develop in tandem.

4. Supply Chain and Expertise

A survey of supply chain stakeholders undertaken by SEAI (2014)[37] determined that one of the greatest challenges to developing a sustainable energy supply chain in Ireland is the *need for adequate skills*. The skills required in offshore wind are varied and unique to each stage of a projects lifecycle. Specialised fabrication and manufacturing skills are necessary for the numerous components involved; ranging from the large scale rolled steel required for XL monopiles to specialised carbon fibre knowledge for turbine blades. The installation process is a short term requirement (1-3 years) that needs expertise in offshore processes including pile hammering, and heavy crane lifts offshore. Whereas, operations and maintenance require long term expertise (20 years +) in wind turbine repairs, ranging from annual predetermined maintenance to the corrective maintenance and replacement of large turbine blades. These activities require skills that are not currently present in Ireland.

Furthermore, the lifecycle processes of offshore wind need to be supported by an effective supply chain. An offshore wind farm contains numerous components (Table 6) for its initial construction and as spare parts for operation and maintenance. At present, these can be sourced at various locations across Europe, and transported for use to an installation port on the Irish coast. However, many of these components are very large, and difficult to transport, leading to some serious logistical problems.

Component	Break-down
Turbine	Tower
	Blades
	Spinner
	Nacelle Cover
	Control System
	Generator
	Gearbox
	Main Shaft
Transition Piece	Transition Piece
Foundation	Foundation (i.e.: steel or concrete structures)
Substation	Transformers
	Switchgear
	Reactors
	Backup generator
	Water tanks
	Substation foundation
Cabling	Inter-array cables
	Export cables

Table 6: Components in an offshore wind farm [Source: Crown Estate [38]*]*

This section explores the skillsets and industries present in Ireland that would benefit the offshore wind industry development and considers their impact on the supply chain.

4.1. Offshore Industry Expertise

In comparison to its European counterparts, Ireland has a limited established ocean economy. The Irish Ocean Economy is worth €1.2 billion GVA – an equivalent of 0.8% of Irelands GDP – and provides 16,000 jobs. Across Europe the offshore wind industry has adopted numerous skills from the oil and gas industry. However, offshore oil and gas production contributes 4% of Ireland's ocean economy, whilst 65% of this economy is attributed to shipping and marine tourism (Figure 17). Hence limiting the transferrable skillsets that could be taken advantage of by the offshore wind industry.

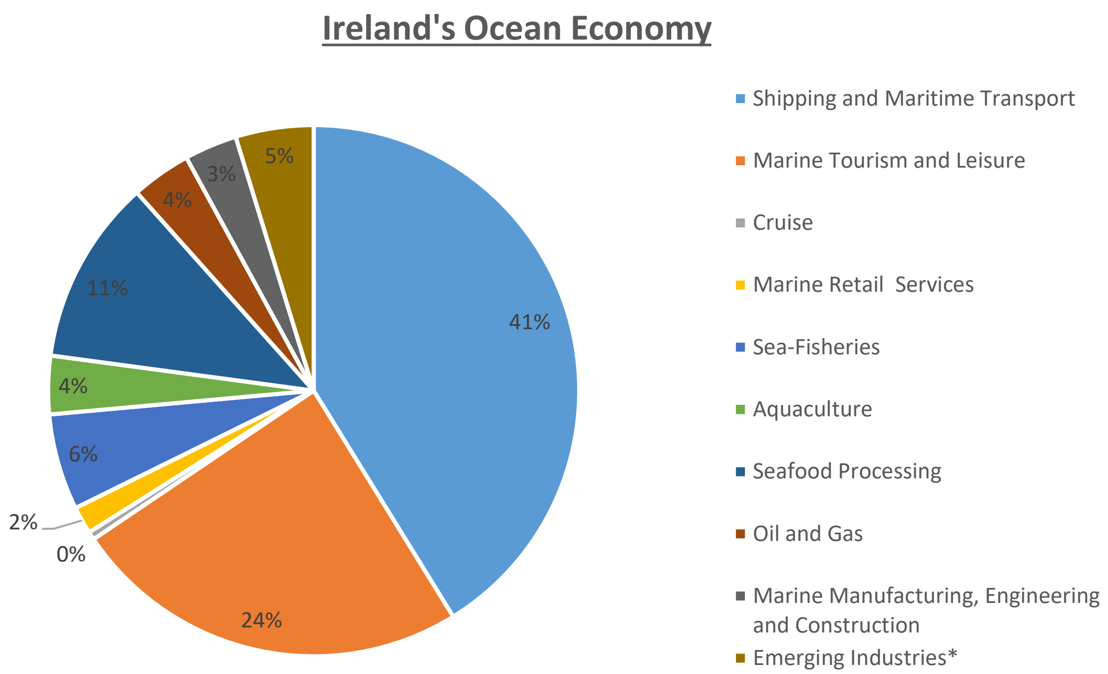

Figure 17: Ireland's ocean economy. Emerging industries includes renewable energy, high tech marine products and services, marine commerce and marine biotechnology and bio products.[Source: Irelands Ocean Economy 2010 [39]*]*

The exploitation of transferable skills has been most beneficially seen in the oil and gas industries in both Norway and the United Kingdom. The United Kingdom has benefitted from being the second greatest producer of offshore oil and gas in Europe (33%)[40], using its experience in managing complex offshore projects to accumulate 12,288 MW of consented offshore wind, equal to 50% of Europe's share. However, Norway, who have no offshore wind opportunities currently consented, have utilised their world-leading knowledge of the offshore oil and gas industry to generate a supply chain worth €3billion per GW of installed capacity of offshore wind [41]. They have transferred their skillsets to suit the requirements of the surrounding markets of Belgium, Denmark, Germany, the Netherlands and UK who in some cases have a less established supply chain suited to offshore wind[42].

Ireland has limited transferrable skill sets from the oil and gas industry, and therefore, needs to take advantage of the knowledge of its surrounding countries with experience in large complex offshore projects to learn and train for future self-sustainability. However, Ireland can benefit from its shipping and maritime transport, and marine tourism and leisure experience. As an island, Ireland has high interactions with the ocean with 90% of all import and export being generated via maritime routes.

4.2. Supply Chain

Figure 20 depicts a typical supply chain for the offshore wind industry detailed from [43] highlighting four main regions: preliminary; procurement; installation and quality assurance; and operations and maintenance.

Whilst Ireland does not fabricate any large scale offshore wind components, it has contributed smaller components to the offshore wind industry, and does manufacture components for its large terrestrial wind industry. Ocean Energy Ireland's supply chain database [44] (Figure 18) identifies 121 separate companies and services that can cater for the offshore wind industry. The database includes companies that can contribute across the entire lifecycle process of an offshore wind farm, from design and development to maintenance and vessels. Many of these companies have already aware of the opportunities of offshore wind in Ireland, and have expressed an interest in being involved.

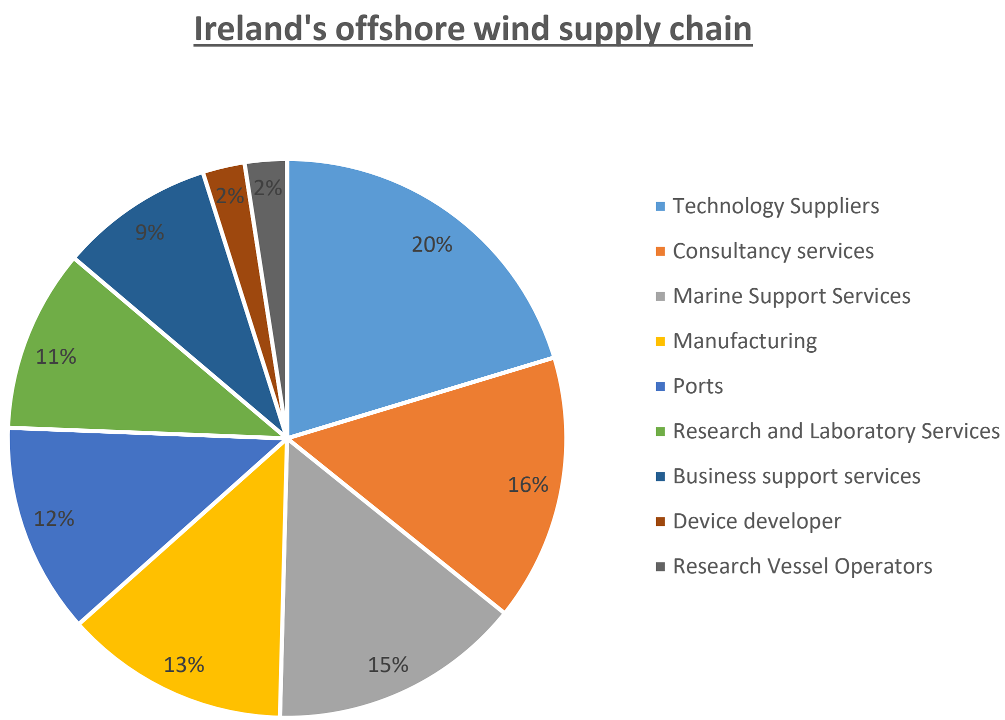

Figure 18: Irelands offshore wind supply chain [Source: Ocean Energy Ireland [44]

Table 7 highlights some of the companies present in Ireland and their experience in the offshore wind industry and/or their potential transferrable skillsets that would benefit from the development of offshore wind. It shows the diverse skillsets that are already present and illustrates how these could be built upon as the economy of scale develops within the offshore wind industry. For example, at present ÉireComposites do not manufacture blades suitable for offshore turbines, they do have expertise in glass fibre and carbon fibre moulding which could be developed with external expert guidance and suitable infrastructure investment. Fabrication of blades in Ireland is more prevalent due to the delicate nature of turbine blades and the complexity in their shipping. Furthermore, MeasureSoft do not currently cater for the offshore wind industry, but with expertise in specialised SCADA software a growing offshore wind industry may be beneficial.

Company	Location	Sector	Experience
AirconMech	Wexford, Cork, Dublin	Manufacturing	Provided the cooling systems on 140 turbines for the Greater Gabbard offshore wind farm in the UK.
ÉireComposites	Galway	Manufacturing	Manufacture 14m blades for onshore wind turbines. Researching the use of powder epoxy in manufacturing 60m – 100m blades in the H2020 project PowderBlade.
ESB	Ireland	Utility	Development of Habitat Cable Repair System, experience working on subsea cable repairs (Moyle Interconnector, Aran Islands) and use of innovative fault location techniques [45].
Gavin & Doherty Geosolutions	Dublin	Consultancy	Provide foundation designs, geotechnical monitoring and site investigations for offshore wind farms, with experience working on Neart Na Gaoithe and Rampion. Involved in H2020 projects including LEANWIND, and promote the potential of offshore wind in Ireland.
Harland and Wolff	Belfast (NI)	Manufacturing	Design and fabricate foundations and platforms for offshore wind farms (Humber Gateway) and provide logistics and assembly services (Ormonde and Robin Rigg).
MaREI	Ireland	R&D	Energy based research, development and innovation hub working on numerous H2020 projects designed to support the offshore renewable energy industry.
measuresoft	Dundalk	Technology suppliers	Specialise in SCADA solutions for industry providing data acquisition software for data logging and monitoring.
Effective Offshore Ltd	Falcarragh	Marine support services	Provide specialist training for working offshore, including courses on health and safety

Table 7: Examples of supply chain companies already present in Ireland with past experience or transferable skills suitable for offshore wind.

It is key to note, that whilst these skillsets in the marine environment do exist in Ireland, they do need to be developed to suit the large scale complexity of the offshore wind industry. During this transition the already established offshore wind supply chain that exists around Europe could be utilised. Figure 21 illustrates the European supply chain showing the location of component manufacturers, with the larger components predominately fabricated close to port to allow easy transportation. It highlights that most of the components are fabricated in the proximity of the North Sea – central Europe and the UK – with an understandable lack of manufacturers present in Ireland. As the industry progresses into floating wind, the demand for components will be greater along the Atlantic coastline – from Ireland down to France, Spain and Portugal. This opens an opportunity for Ireland to enter the supply chain as key manufactures of components aimed at floating wind. The export of components could be accommodated by Shannon Foynes port, an international gateway with good infrastructure links and ability to handle the largest vessels [46]. The export of components could be conducted along the

Atlantic route which is less busy than the passage through the Channel (Figure 19) from the key manufacturers already established in the proximity of the North Sea.

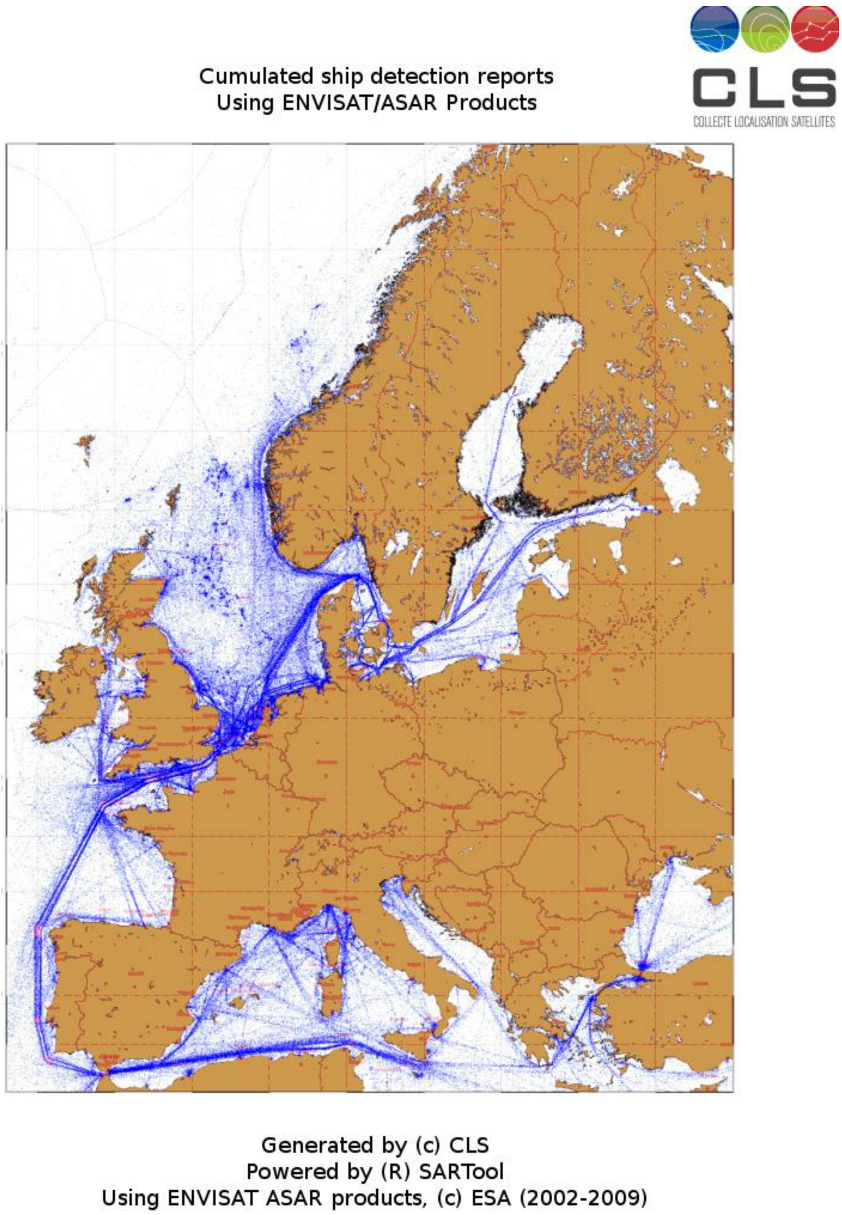

Figure 19: Europes main shipping routes. [Source: ESA [47]*]*

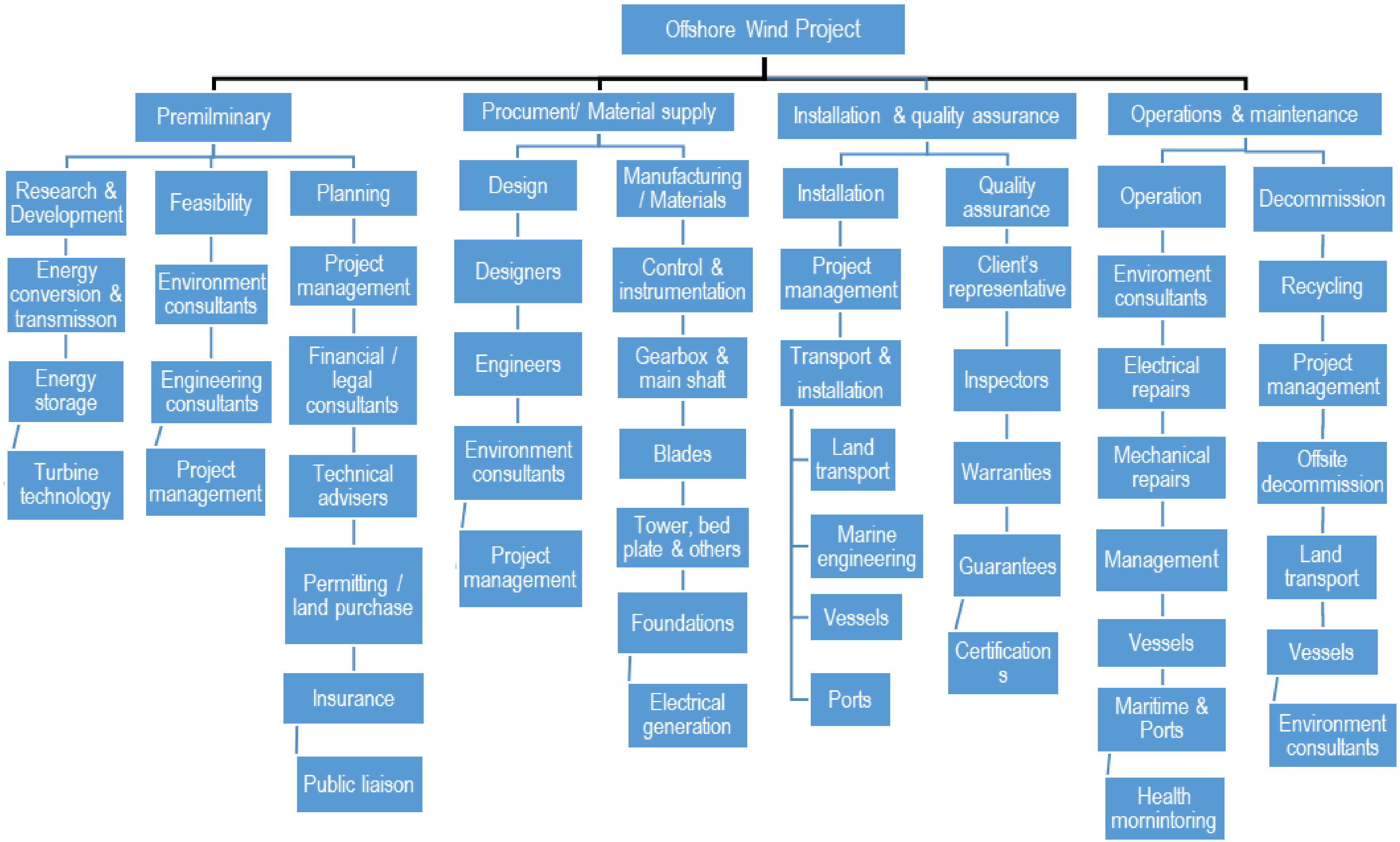

Figure 20: Offshore wind supply chain [Source: Dinh and McKeogh, 2018 [43]*]*

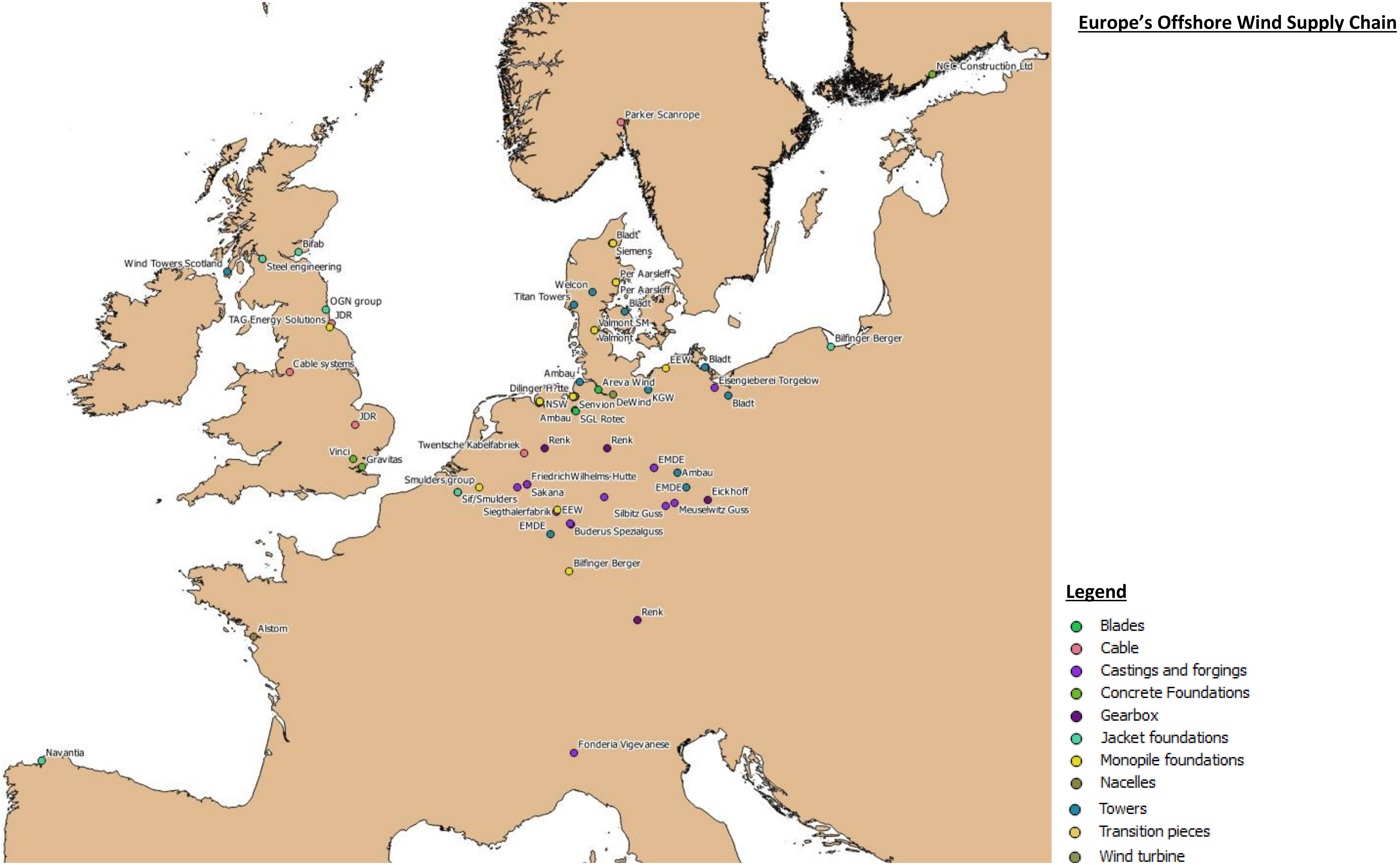

Figure 21: Europe's offshore wind supply chain. [Source: LEANWIND GIS]

4.3. Potential Job Creation

Economic analysis indicates three construction job years per MW of offshore wind deployed with 0.6 FTE jobs in ongoing operations and maintenance [48]. Additionally, benefits will be derived from enterprise and employment associated with large-scale offshore wind projects and supply chain. A study of potential job creation in the US indicated that in total 248,580 equivalent job years would be created by supply chain sub-elements of in the low case scenario (4GW) of US offshore wind[49]. A study conducted for the 2018 iPORES report has deduced a baseline peak total FTE potential of 2,900 jobs by 2025 (Table 8) – the year offshore wind can be expected to be commissioned offshore.

The significant figures of indirect employment in broad industrial sectors related to the UK offshore wind industry are estimated by using industry input/output relationships[50]. These include:

- Extraction and utilities (agriculture, forestry and fishing, mining, and quarrying).
- Construction and manufacturing.
- Professional and business services (information and communication, finance and insurance, property, professional, scientific and technical, business administration and support services).
- Other services (motor trades, wholesale, retail, transport and storage, accommodation and food services, education, health, and public administration).

Taking the sum total of direct, indirect and induced employment, the total number of full-time equivalent jobs associated with the UK offshore wind industry is expected to increase from 30,000 in 2017, to approximately 58,000 by 2032. This is reflective of a growth from 6.8 GW installed capacity to 22.5 GW in 15 years. Hence, the potential for job creation in Ireland is high if it meets its targets for offshore wind.

Potential Job Creation	Baseline	High deployment	Low deployment
Capacity Deployed	1,505 MW	5,200 MW	1,005 MW
Person years of employment	18,000	60,000	12,000
Construction phase	10,000	36,000	6,800
O&M	2,700	7,100	2,100
Indirect and induced	5,300	17,000	2,900
Peak total FTE Employment	2,900 (2023-5)	7,100 (2026-30)	1,800 (2023-5)

Table 8: iPORES (2018) [36] Estimated potential job creation

4.4. Conclusion

At present the Irish supply chain and expertise is not sufficiently established to solely support the offshore wind industry in Ireland. However, this is not expected of a country at the beginning of its progression into the industry. Components will be fabricated in a range of countries across Europe and imported, especially during the first few years of development. Ireland can utilise these established networks whilst it works to identify its own niche areas.

Ireland does contribute some components to the offshore wind industry such as foundation design and turbine cooling systems and, as an island, has a great deal of experience in maritime vessels. This, in combination with its unique metocean conditions, could prove beneficial in the development of innovate technology and methodology to produce a supply chain to other countries with similar characteristics – specifically France and Portugal. In the long term there looks to be the potential to develop a supply chain and benefit from its associated job creation

4.5. Recommendations

In summary, the following recommendations are made to the offshore wind industry in Ireland:

- Utilise the existing supply chain outside of Ireland for the first offshore wind farms
- Develop the existing supply chain in Ireland for smaller components
- Develop own supply chain niche areas as pipeline of projects develop, and become leaders in the export of innovative components.
- Continue with R&D, offshore training and renewable education.

5. Conclusion

The need for government support with clear consenting processes reoccurs throughout all the issues facing Ireland towards its development of an offshore wind industry. Clarity on a national policy for the roll out of offshore wind would give the supply chain confidence to develop with opportunities for both indigenous companies and international companies to establish in Ireland. In addition developers would invest in and back regional ports on their path to support the offshore wind industry. Whilst the beginning of Irelands development towards offshore wind does not require major support from Irish manufacturers and facilities, this support is important in the long term in order for Ireland to maximise the benefits that this developing industry can provide. Ireland does have an opportunity to become a leading player in the wind industry. Its high offshore resource has the potential to generate significant energy and its vast EEZ and metocean conditions could provide a key breeding ground for innovative technology, for both support vessels and floating platforms.

However, a greater sense of urgency is required to progress the development of offshore wind in Ireland and this has been well highlighted [51][37][37][36]. In 2014 the OREDP [48] outlined the Irish governments optimism to install 500 MW of offshore energy by 2020. Instead Ireland are failing to reach its targets with only 25.2 MW at the end of 2018, and it is unlikely this will alter in the next two years with little progress on the MAFA bill or MSP base report. As soon as offshore wind farms prove their bankability in Ireland developers will take advantage of the high resource. However, bankability requires visible project pipelines and commissioned offshore wind farms operating to instil confidence and reduce risk.

The Irish government, offshore wind developers, manufacturers, port business developers and supply chain firms are all aware of Ireland's potential for harnessing its offshore energy and the associated economic and environmental benefits. However at present, there is a lack of urgency in government departments to provide the necessary resources and frameworks to enable the industry develop. This report has outlined a number of challenges and opportunities for Ireland and with lifetime windfarm costs continuing to decrease and the viability of the technology proven, it is now both timely and necessary for Ireland to get behind offshore wind.

6. Recommendations

In summary, the following recommendations are made to ensure a successful development of the offshore wind industry in Ireland:

- Stronger commitment from government to enable the development of a pipeline of projects, prove bankability and instil confidence into the industry so it can gain support and investment from developments.
- Opportunities to develop innovative technologies, methodologies and supply chain that are suited to Irelands marine environment
- Requirement to develop port facilities so that they can support the offshore wind industry.
- Ongoing offshore wind related research and development, offshore training and education to ensure there is a continuous supply of expertise.

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