IMIA WORKING GROUP WGP 131 (23)

FLOATING OFFSHORE WIND: RISK MANAGEMENT & INSURANCE

Source: DNV

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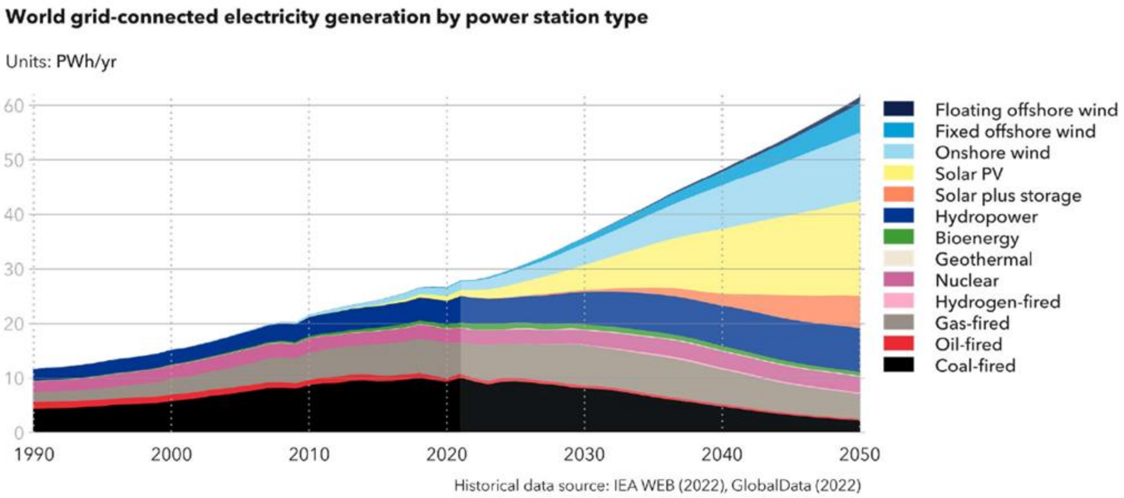
1 Executive Summary: why Floating Offshore Wind?

The world is transitioning away from fossil fuels and towards renewable energy sources. With an anticipated share of roughly 33% of the world's electricity production by 2050, wind energy is set to play a key role in this transition[1]. Today most wind energy is generated onshore, though offshore wind is gaining in importance as it promises new wind resources with much higher capacity factors. Widespread political support for offshore wind is driving significant growth targets. As a result, it is anticipated that offshore wind will account for ~13% of global electricity production by 2050 (thereof 11% fixed bottom and 2% floating)[2]. For floating this means that the installed capacity is supposed to grow from less than 0.2GW today to around 250 GW over the next 30 years (DNV ETO).

Figure 1: World grid-connected electricity generation by power station type



Source: DNV (2022): Energy Transition Outlook (ETO) 2022

This staggering growth ambition will create significant investment opportunities, but also significant risks. It is safe to say that floating offshore wind marks the next frontier in the offshore wind industry. Deep-water locations far from shore, harsher weather conditions and unproven technology pose significant challenges to risk management.

Our mission:

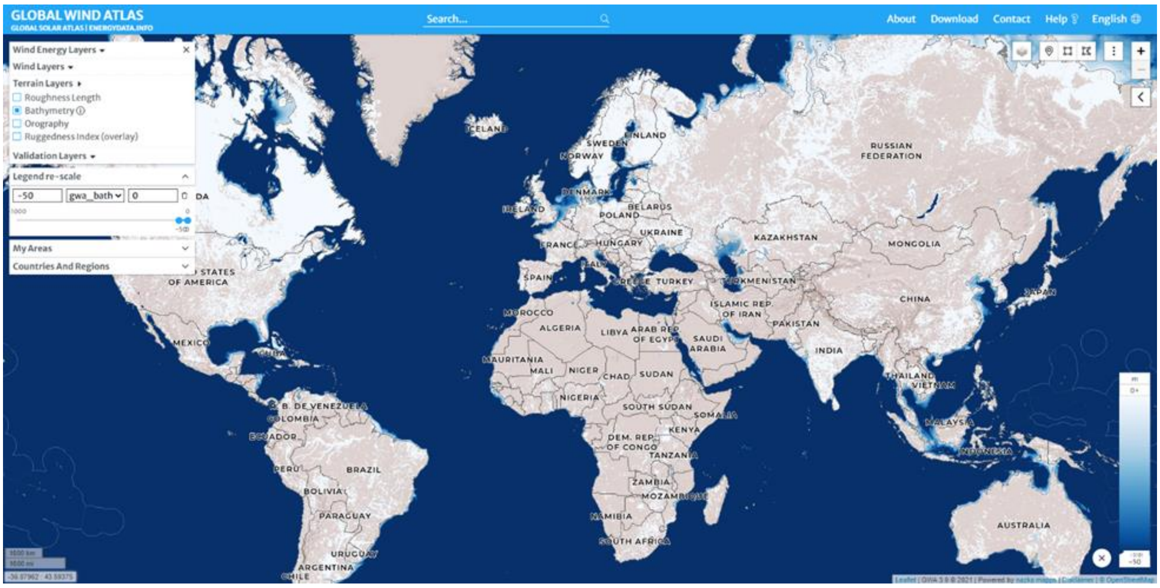
- Explore the industry and technological background of floating wind
- Support assessment of emerging technical risks
- Enable educated decisions concerning underwriting and claims management
- Create awareness and support risk management best practices
- Initiate risk management discussions to ensure long-term insurability and bankability
- Contribute to the growing community of risk management professionals in floating offshore wind

2 Floating Wind Industry Overview

The idea behind floating wind

From its beginnings in the early 2000s till today, the offshore wind industry is mainly driven by bottom-fixed projects which typically require water depths not exceeding 60 meters. Along with requirements concerning wind speeds (typically at least 7m/s at hub height), this limits the suitable locations for bottom-fixed offshore projects to certain coastal areas. As you can see on the map below the main areas of focus are currently: North Sea, Baltic Sea, Irish Sea, Strait of Formosa. The idea of floating wind is to develop a technical way to exploit many of the promising wind resources which sit in deeper water locations, thereby truly leveraging the global opportunities of offshore wind.

Figure 2: Global Wind Atlas

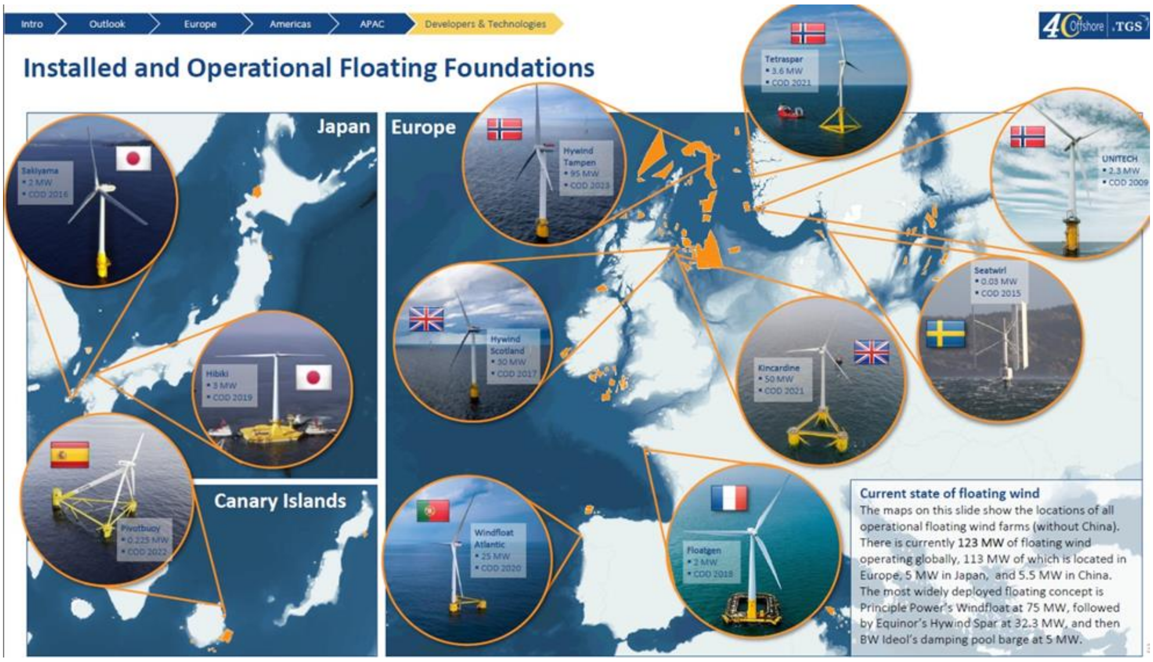


Source: Global Wind Atlas © 2023DTU - light blue areas show limited potential regions for fixed bottom offshore wind based on water depth[3]

From prototypes to world-scale projects

Early floating concepts have been tested since the late 2000s and ever since a handful of pilot projects and scale-ups have emerged. As of today, there is roughly 120MW of installed floating capacity, with the largest operational projects being Kincardine in Scotland (50MW) and (once taken over) Hywind Tampen in Norway (95MW)[4]. However, these projects appear small when compared to the significant announcements which were made recently. For instance in the Scotwind tender 10 floating projects were awarded, many of them in the GW-scale[5].

Figure 3: Installed and Operational Floating Foundations



Source: 4COffshore (2022): Floating Wind Progress Update: H2 2022

Key markets and players

The rise of floating wind allows for the globalization of the offshore wind market, which is still heavily focussed on Europe. Looking at the key markets in the table below, it is clear that plenty of challenges lie ahead when it comes to local regulation and supply chains as well as country specific risk factors such as natural perils and political risks.

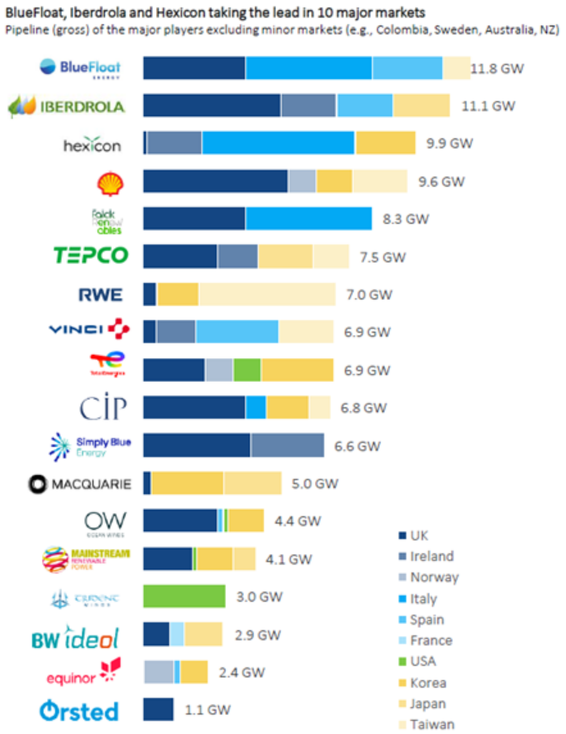
Figure 4: Top 30 Floating Wind Markets

North & South America	Northwestern Europe	Southern & Eastern Europe	Africa	Asia & Oceania
US Pacific	Ireland	Croatia	Kenya	New Zealand
US (Rest)	Norway	Bulgaria	Morocco	Philippines
Costa Rica	Sweden	Greece	Egypt	Australia
Dominican Rep.		Portugal	South Africa	Vietnam
Colombia		Romania	Tunisia	
Chile		Spain		
Mexico		Italy		
Brazil		Turkey		
Canada		Russia		

Source: Global Wind Energy Council (2022): Floating Offshore Wind – a Global Opportunity

The projected market growth is attracting plenty of new players from various industries including traditional players from the utility space, but also new entrants from the oil & gas as well as the infrastructure industry. Some of them will bring previous relevant offshore experience with them, while others are facing a steep learning curve. Experience will therefore remain a critical aspect to be considered in floating offshore wind projects.

Figure 5: BlueFloat, Iberdrola and Hexicon taking the lead in 10 major markets

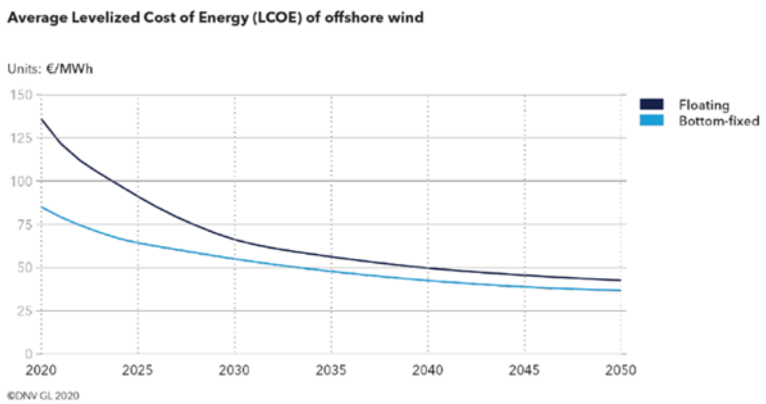


Source: 4COffshore (2022): Floating Wind Progress Update: H2 2022

Cost development

The key metric to compare the cost of electricity sources is the levelized cost of energy (LCOE). As can be seen in the chart below, the LCOE of floating wind will come close to bottom-fixed offshore wind by 2030, which indicates a rapid uptake of technology and evolving economies of scale.

Figure 6: Average Levelized Cost of Energy (LCOE) of offshore wind



Source: DNV (2020): Floating Wind: The Power To Commercialize

Outlook and key challenges

Today the floating wind industry is still in its infancy and there are a number of key challenges which must be tackled to ensure the growth aspirations can be met in a safe and sustainable manner[6]:

- Economies of scale and standardization: in order for costs (LCOE) to reduce as projected, there must be economies of scale and fast industrial learning. The latter is typically achieved by standardization. This involves, among other things, the reduction and simplification of designs to allow for mass production as well as a focus on compatibility of key components such as floaters, mooring systems and turbines to allow for efficient deployment across projects. The latter is also important when it comes to considering efficient operation and maintenance (O&M) along the asset life cycle (e.g. supporting cost-efficient repairs in local yards). Hence it is likely that there will be further consolidation around key components such as floater designs and manufacturers.

- Supply chain issues: spanning from the US to Asia, the floating offshore industry will create plenty of opportunities for yards, vessel companies, OEMs and other offshore service providers. While some countries have an established offshore industry, others are starting from scratch. This in turn means that global supply chains will need to be aligned with local delivery and content requirements. Therefore, we are expecting an increased focus on the suitability of local supply chains (e.g. suitable yards) and continued pressure on global supply chains (e.g. shortage of raw materials and vessels). We discuss these issues in more detail in Chapter 4 (Supply Chain & Logistics).

- Industry standards & certification: floating wind is the next frontier of the offshore wind industry and poses significant challenges around technology and design standards. Today there is a wide range of applicable standards and it is likely that these will be harmonized as the industry emerges. Also, greater emphasis will be placed on project certification as an efficient tool to ensure long-term bankability and insurability. We explore the ongoing challenges around this topic in Chapter 6 (Risk Mitigation, Certification & Standards).

- Risk management as a priority: steep growth targets and plenty of new entrants with varying levels of experience suggest that risk management may not be on top of the list of current projects under development. This is likely to change as projects get bigger and need to be both bankable and insurable. Also, more and more assets are entering operation and start facing challenges around O&M (see Chapter 5 (Operations, Maintenance & Repair)). That said, we believe that the discussions around risk management will intensify in the future.

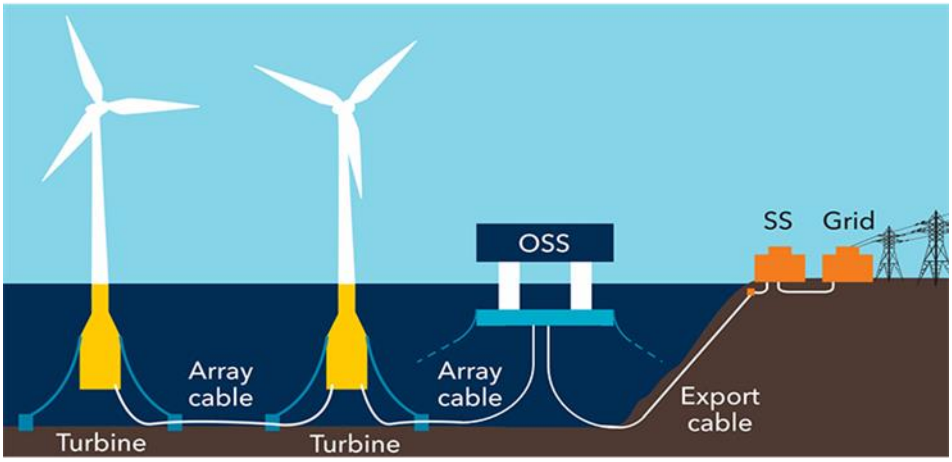
Key takeaways:

- Floating offshore wind is still in its infancy, but many factors suggest that it is going to be a key part of our future energy system
- As it scales up, floating wind will likely globalize the offshore wind industry and create opportunities around the world
- Costs are likely to come down significantly as the industry matures, but risks are likely to increase in the short term as there is still a lack of proven operating experience
- Along other challenges which need to be tackled, risk management is a priority to ensure long-term bankability and insurability

3 Floating Wind Technology

A floating offshore windfarm (FOWF) consists of several assets (wind turbines, floaters, offshore substation, power cables) as shown below. All of these assets have to be considered separately from a technical perspective to manage project risk and ensure successful operation throughout the full asset lifetime. Apart from the individual assessment of the different assets and technologies, a key risk lies in interface management. It is worth noting that FOWFs bear a high level of project specific design, engineering and project execution challenges. Therefore, standards and the certification process which include site assessment, design basis, fabrication, transport and installation, commissioning, operation, lifetime extension and decommissioning play a key role for risk assessment (see also Chapter 6 (Risk Mitigation, Certification & Standards)).

Figure 7: Floating wind farm assets



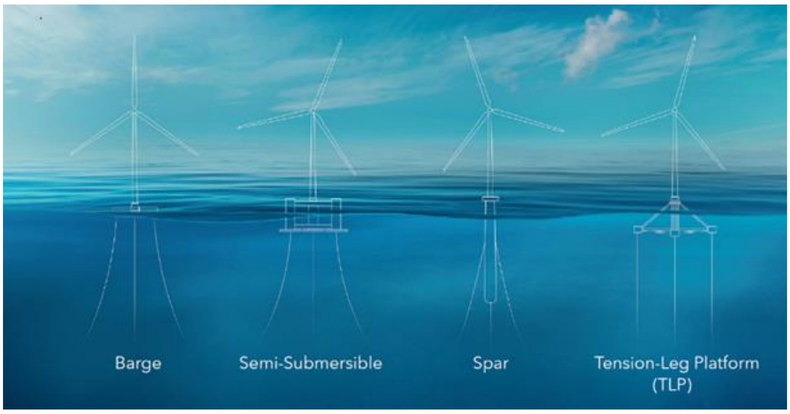
Source: DNV

3.1 Main Floater Concepts

A FOWF "platform" or "floater" is the concrete, steel or hybrid substructure on which the floating offshore wind turbine (FOWT) is installed, providing it with buoyancy and stability. At the time of writing (2023), numerous floater concepts are being designed and developed. However, by classification, there are four main types of floaters, namely: Spar-buoy (Spar), the Tension Leg Platform (TLP), the Semi-submersible and the Barge-type.

The choice of floater will depend on the following: sea and seabed conditions; the winds in the area; the size of the FOWT, the depth of the harbours, available manufacturing facilities; and price of materials and equipment. It should be noted that the motions of the floater are dependent on the aerodynamics of the FOWT and the hydrodynamics of the mooring system. The main floater concepts can be seen in the diagram below.

Figure 8: Types of floater concept



Source: DNV

3.1.1 Overview of Main Floater Concepts

Spar

A Spar is a large diameter vertically buoyant cylinder, which is ballasted (at the bottom end) with a deep draft, which makes the structure less responsive to wind, waves and the current. The Spar type is kept in position by catenary or taut spread mooring lines with drag or suction anchors. Buoyancy is provided by the geometry of the cylinder, while stability is provided by the weight which is at the lowest possible point.

Tension Leg Platform (TLP)

A TLP normally consists of columns and pontoons. The unique feature of the TLP is its mooring system, which has vertically tensioned tendons. These tendons provide stability to the structure. The TLP structure is vertically restrained, precluding vertical motion (heave) and rotation (pitch and roll). Technically, the platform does not float once the turbine is installed on it.

Semi-submersibles

Semi-submersibles typically consist of multiple columns and pontoons. The columns mainly provide the stability, while pontoons provide additional buoyancy. The floating structure is kept in position by a mooring system, consisting of catenary or taut spread mooring lines and drag or suction anchors.

Barge

In the same way as the Semi-submersible, the Barge concept is a waterplane-area stabilised structure. The main difference between a Semi-Submersible and a Barge is that a Semi-submersible has distributed buoyancy and consists of columns, while a Barge is typically flat without interspaces. The length and width of a Barge floater are significantly larger than the draught (height).

At the time of writing, the 4C offshore database records that the Semi-submersible floater type is the preferred option among most small-scale projects.

Some more detailed advantages and disadvantages of floaters are described below in the table:

Figure 9: Advantages and disadvantages of floaters

Key types	Advantages	Disadvantages
Spar	Simple structure. Inherently stable due to centre of gravity below centre of buoyancy. Less responsive to wind, waves and current.	High structural mass. Long cylinders required for large FOWT. Potential for high heel angle and acceleration at the FOWT. The large draft limits the deployment potential to sites, required water depth >~80m. The large draft requires a deep-water port to support shore-based maintenance.
Tension Leg Platform (TLP)	The most stable floating concept. A smaller and lighter structure than the Semi-submersible and Spar designs which means lower material cost. Installed in a range of water depth from 40m. Shallowest draft among all the typologies allowing for quayside assembly. Smallest footprint.	TLPs have most expensive anchoring system and high vertical tension on mooring tendons and anchors. Fatigue loading on the mooring system, instability if tendons fail. Transit during installation is challenging due to instability – requires a specialist support barge for transportation to the site and stabilization during final installation.
Semi-Submersible	Due to the shallow draft, (relatively) simple transportation and installation. Assembly can take place onshore in a dry-dock. Shore-based maintenance can be performed in a dry-dock or quayside. The cost of anchoring system is low. Can be deployed in 40m or less with appropriate mooring system.	High structural mass required to achieve buoyancy. Requires active ballast system if the turbine is on the outer column. Potential for high heel angle and acceleration at the turbine.
Barge	The shallow draft assembly can be performed onshore in a dry-dock. Can be installed in a wide range of water depth in 40m or less.	High structural mass required to achieve buoyancy. Requires a dry-dock in order to manufacture the concrete foundation. Prone to corrosion due to the inner water plane area.

3.1.2 Case study and Risks Observed

There are a number of pilot FOWF projects which demonstrate the feasibility of the floating concept(s). In the following table we introduce some of the key risks which have been observed in small-scale projects:

Figure 10: Key risks

Construction risks	**Fukushima Hamakaze Spar floater tilted during ballasting – Japan** In 2016, the floating advanced Spar foundation capsized in Osaka Bay during ballasting operations. The intention was to allow water into the floater to stabilize it on the shallow seabed, in preparation for the installation of the 5MW wind turbine. This incident delayed the project by five days.
	SKWID Sinks - Japan A Floating Wind & Current Hybrid Power Generation System (SKWID) constructed by MODEC sank during installation. The identified location is 1.2km off the coast of Kabe Island. The cause of incident is unknown.
Operational risks	**Saitec floating turbine capsizes off Spanish coast – Spain** In 2020, Saitec Offshore Technologies' BlueSath FOWF testing platform capsized following Hurricane Epsilon. Faced with wave of up to 10 metres – equivalent to 60 metres at full scale - the reduced 1:6 scale model of a FOWT installed off Santander was unable to remain upright.
	Kincardine repair issues – Scotland In 2022 a FOWT had to be towed to a port for repairs. As a result of a lack of local ports suitable for the repair , the FOWT had to be towed fromthe project site in Scotland all the way to Rotterdam in the Netherlands.

Even though some floater concepts have been successfully tested in demonstrator projects, the risk examples mentioned above demonstrate that floater technology is still in its infancy. Continued effort is required to standardize designs and to focus on interface and supply chain risks.

3.2 Mooring Systems

Unlike the traditional shallow water fixed bottom wind turbine structures that are physically connected to the seabed, FOWFs have no direct contact to the seabed, and require the use of moorings to stay in position.

The use of mooring systems is nothing new to the offshore oil & gas industry as these are routinely utilised to moor the various deepwater floating production platforms and FPSOs in position. However, these deepwater mooring configurations are not necessarily easy to transfer directly to the FOWF industry.

The key difference between the deepwater oil & gas and FOWF structures is the operating water depth. The dynamic loading experienced by floating structures in shallow waters (60-300m) is vastly different compared to that experience in deepwater locations (>1000m).

In shallower water depth locations, other factors impacting on the mooring design include more varied geological seabed conditions and potentially an increased exposure to seismic hazards such as liquefaction, seismic settlement, lateral spreading and earthquake loads, including the potential for seismic induced sea waves (tsunamis)[7].

Prevailing and regional weather conditions are also important design considerations. For example, the potential exposure to severe weather such as typhoons and hurricanes will have a significant impact on how such mooring systems are designed.

3.2.1 Mooring Configurations

Typical mooring configurations are based on taut, semi-taut or catenary mooring designs that transfer loads acting on the floating structure to anchors installed in the seabed[8].

Variations on the mooring configurations are also being considered, including concepts linking separate floating structures together into clusters (i.e., in a honeycomb-like configuration). This should reduce the number of subsea mooring points. In addition, the inclusion of quick-disconnect systems is considered to enable immediate disconnection if turbines are towed back to port for maintenance or repair work.

3.2.2 Mooring Anchor Systems

In order for FOWF structures to maintain station-keeping at location, the mooring lines need to be securely anchored to the seabed. The type of anchoring system used is dependent on the geological condition of the seabed. Examples of anchoring systems include suction caissons, anchor piles and drag anchors.

Some of the planned FOWFs consist of 50-100 floating structures with between 3 to 4 mooring lines each which could mean approximately 400 mooring lines. A study conducted by the World Forum Offshore Wind (WFO) Insurance Subcommittee identified certain scenarios where the FOWF could potentially be equipped with larger number of mooring lines to allow for redundancy for avoidance of a total loss scenario of individual FOWF units[9]. With or without redundancy, this is still a large increase in mooring lines compared to the known deepwater oil & gas floating structures that are usually a single large structure with approximately 8 to 10 mooring lines. This significant increase in the number of mooring lines and anchoring systems requires special attention.

The subsea anchoring pattern for FOWFs can be quite complex, depending on the prevailing wind and wave directions, and the type of anchoring system deployed. This is further complicated by the close proximity of the individual floating turbine structures to each other and the addition of inter-array cables. For this reason, the design phase of the wind farm layout needs to be carefully planned with input from both the mooring and cable engineers to minimise any potential clashing or crossing issues between the components. It must be noted that floating projects, even though not directly connected to the seabed, face significant geotechnical risks. This is especially where anchor piles or caissons are used which could result in hundreds of repetitive operations per project.

3.2.3 Mooring Inspections

Considering that individual floating offshore wind structures are typically moored in position with only 3 or 4 mooring lines, there is very little to no redundancy in the mooring system. As such, regular inspections could allow for earlier intervention should anomalies be present (e.g. chain corrosion or marine fouling on synthetic rope). Additionally, the inclusion of reliable mooring line monitoring systems could help with the integrity management of the mooring lines over the course of their service life. This was re-iterated by leading offshore experts at the WFO Moorings Subcommittee, who stated that *"…the implementation of a Mooring Integrity Management that consists of a reliable tension and motion monitoring system combined with risk-based inspection and maintenance with a proactive spare part strategy can significantly decrease the mooring line failure rate and mitigate the consequences of an eventual failure.*[10]"

3.2.4 Mooring Failures and Associated Risks

The risks associated with mooring failures are widely known to the oil & gas sector and insurance industry. However, this is a new kind of risk to the offshore wind industry.

The key risk associated with the failure of a mooring system is loss of position. This is heightened if FOWFs are tethered to adjacent floating structures in a honeycomb mooring concept. Additional risks associated with mooring failures are the sinking or capsizing of the FOWT itself and damage to attached cables and auxiliary components.

3.3 Cabling systems for floating wind offshore

Historically, subsea cables are responsible for a substantial proportion of losses in the offshore wind sector. It is therefore not surprising that the need for robustly designed and built dynamic cables are becoming a focal point within the offshore wind sector, as these are critical for transferring wind generated power from the FOWTs to the sub-stations. Compared to cables used in fixed bottom turbine configurations, dynamic cables are relatively new components, which require more stringent quality control during their manufacture and a different approach in terms of inspection and maintenance.

Dynamic cables for floating offshore wind applications will be constantly exposed to dynamic environmental loads and must withstand the constantly changing loads caused by waves, ocean currents and the movement of floating equipment. Consequently, they are subjected to higher mechanical stress throughout their life cycle.

3.3.1 Cable Types

For the FOWF industry, submarine power cables can mostly be divided in two categories, grouped by type of usage. The different types of cable are set out below.

IAC (Inter-array Cables)

IACs are always MV (**medium voltage**) submarine power cables, connecting FOWTs with each other and strings of FOWTs to corresponding sub or converter stations. These cables typically have a voltage level of 33 to 66 kV. Dynamic IACs are currently certified and deployed but they have limited operational experience.

Export cables

Export cables are either HV (**high voltage**) alternating current (**AC**) or direct current (**DC**) submarine power cables. These cables connect the Offshore Substation (**OSS**) to the Onshore Substation and have a typical voltage level of 150 to 220 kV (for AC) or 200 to 329 kV for DC connections.

For export cables, currently no certified and deployed dynamic cable design with a voltage level above 145 kV is available on the market.

To date, cables used by fixed bottom offshore wind turbines have all been of a static design. These cables have been designed to survive a limited number of cyclic loadings over their operational life. FOWFs require cables specifically designed to withstand dynamic cyclic loading over the complete lifecycle of the cable.

Key design differences between static and dynamic cables:

Figure 11: Key design differences

Key Layers	Key differences of dynamic and static cables

Outer Sheath	A more robust outer protective sheath is required for dynamic cables (PE, Nylon or similar solid extruded cover). There is a general agreement within the industry that dynamic cables should have an extruded outer sheath.
Armouring	Dynamic cables require an even number of **contra-helical** armour wires, which is necessary to increase the torsional stiffness to withstand the dynamic loads the cable will experience over its lifetime.
Conductor Sheath	Dynamic cables require a friction reducing layer between the sheath and adjacent layers to lower the friction coefficient between the layers in order to lower the bending resistance. Without this friction reducing layer, the risks of wear and abrasion on the sheath surface is significantly increased.
Conductor Core	Dynamic cables require a larger conductor diameter compared to static cables in order to reduce heat losses. A solution must also be found for thermal issues in the dynamic cable in the bend stiffeners.
Water Barrier	Dynamic cables are likely to require a corrugated metal sheath in addition to the standard water barriers of static cables.

Figure 12: Key handling differences

Static cables	Dynamic cables
Coil-able in low-cost baskets	Large carousel or reel storage
Sufficient axial strength for shallow installation	Good torsional stability Higher axial strength (max tension)
Lighter in weight	Heavier in weight
More flexible with smaller minimum bend radius (MBR)	Higher stiffness with larger minimum bend radius (MBR)
Poor fatigue resistance	Higher fatigue resistance

The challenges in designing, manufacturing and handling dynamic cables result in a significant increase in cable risks for floating projects. As the dynamic cable industry develops, continued emphasis needs to be put on certification (type tests and entire projects) as well as best practice exchange.

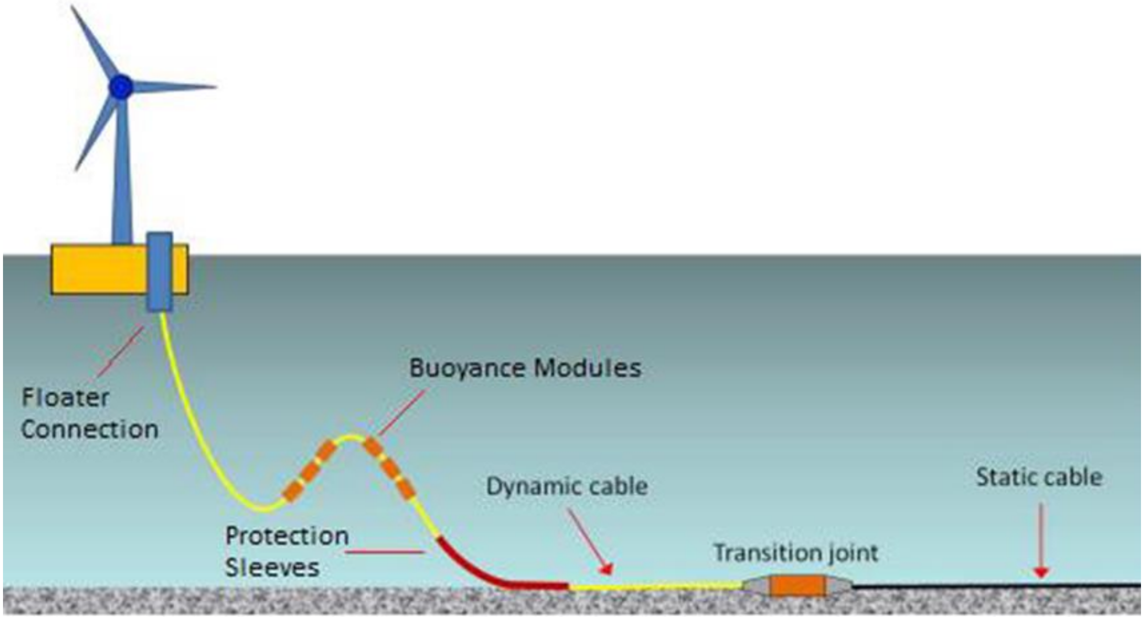
3.3.2 Installation

There are several differences that need to be considered when comparing dynamic cable installation to static cable installation.

Firstly, the connection between different floating structures like multiple FOWTs and the OSS, depending on the cable configuration employed, may require a combination of static and dynamic cables, with the inclusion of a static-to-dynamic transition on the seabed.

Secondly, there may be requirements for the inclusion of additional ancillary components such as bend stiffeners, buoyancy modules and cable protection systems along the different sections of the cable.

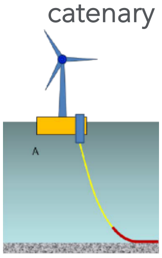
Figure 14: Dynamic cable layout and components

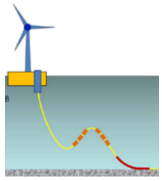
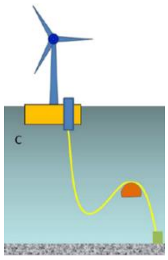
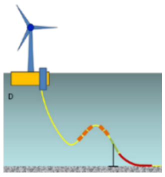
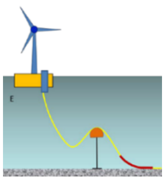


Source: CIGRE[11]

There are several different cable installation configurations to consider, depending on the requirements and limitations imposed on the project. The pros and cons of the different configuration options are summarised in the table below:

Figure 15: Pros and cons of the different configuration options

Configuration	Pros	Cons	Comments
A) Free hanging catenary 	– Simplest configuration. – Does not require buoyancy modules. – Easy to install. – Inexpensive compared to other configurations.	– No decoupling of the motion of the floating structure. – No restriction of lateral movement. – High tension at the hang-off point due to self-weight of free hanging cable. – Prone to compression and buckling at the touchdown point.	– Lowest cost cable solution. – Only suitable for installations with low dynamic motions.

B) Lazy wave  C) Steep wave  D) Tethered wave 	– Simple configuration. – Proven use for deep water applications. – Buoyancy modules to decouple the floating structure motions from the fixed subsea end (static cable). – Inexpensive compared to other configurations. <u>Differences:</u> – Steep wave (C) requires a subsea base and bend stiffener at the touch down point. – Tethered wave (D) requires a tether restraining the touchdown point and reduces touchdown impact.	– No restriction of lateral movement. – Marine growth can result in change of shape of the configuration. – Steep wave (C) and Tethered wave (D) configuration require additional seabed infrastructure.	– Low-cost solution. – Suitable for installations with reasonable dynamic. – Motion with only low currents at the touchdown point. – Needs significant space between floating structure and touchdown point. – Lazy Wave configuration is usually preferred as it requires less subsea infrastructure.
E) Lazy S 	– Buoyancy modules to decouple the floating structure motions from the fixed subsea end. – Subsea buoy and midwater arch reduces effects of cross current. – The design will reduce the tension at the touchdown point. – The key difference between the two configurations is the connection of the mid-water arch of the Lazy S to the seabed and the difference in touchdown point.	– Buoyancy modules and subsea buoy increases the installation efforts of this design. – Requirement for hold down tether and clamp. – Marine growth can have an impact of the components and have to be monitored regularly.	– High cost (mostly not economically suitable for single cable applications, e.g., WTGs). – Suitable for dynamic applications. – Suitable for multi cable applications e.g., OSSs. Most often, the Steep S is preferred due to potential compression problems at the touchdown point.

Source: CIGRE (2015): TB 610 - Offshore generation cable connections

A viable alternative to the above discussed hanging configurations is to replace static submarine cables on the seabed with floating dynamic cables. In such a configuration, the floating structures would be inter-connected using a floating dynamic cable with buoyancy modules installed at discrete locations to allow the cable to form a W-shape. This produces a mid-water floating cable configuration which reduces the axial forces in the cable and results in a better dynamic response. This solution would result in reduced cable length between two floating structures and would remove the need for transitions joints, thereby lowering costs significantly.

However, this concept has not yet been applied to FOWF projects and as such no operational experience is currently available.

3.3.3 Cable Protection

The dynamic nature of the cable configuration is new to offshore wind and introduces additional challenges in protecting the submarine cables. However, lessons learned in the traditional oil & gas industry from installing deep water dynamic umbilicals are available and could be implemented in FOWFs.

There is an array of auxiliary systems that have long-proven track-records in the oil & gas sector in protecting flexible risers and umbilicals, including:

- Cable bend stiffeners to control bending at the connection point into the floating offshore wind structures;
- Bend restrictors along seabed touchdown area to limit and control bending (and abrasion); and
- Buoyancy modules to control and maintain floating cable configurations.

Following the significant CPS issues seen in fixed bottom offshore wind, we anticipate that greater emphasis is placed on CPS and other cable protection measures going forward. That said, attention should be paid to the implications of newly introduced quick-disconnect systems for cables and moorings to facilitate easier disconnection of individual floating structures back to port for any required maintenance or repair work.

3.4 Wind Turbine Technology

The lack of in-field operational experience is the key risk issue that impacts the full scope of the FOWT systems: from design scopes to the installation and commercial phase. Even though comprehensive evaluations, investigations and modelling have been conducted by the FOWTs which tend to operate in harsher environmental conditions. These uncertainties include:

- Installation, maintenance, and operating protocols of the larger 10MW+, 150m+ FOWTs in deeper waters.
- Harsher offshore conditions not currently experienced by shallow water fixed bottom wind turbine design.
- Fatigue failures in FOWT structural components, such as turbine blades, towers, bolted connections and main floating structures due to inadequate design considerations for material strength requirements in harsher and deeper water conditions.
- Losses to main components such as main bearings resulting from increased dynamic loads due to harsh environmental conditions and sway/heave motions of the floater.

Installing floating structures offshore also presents a certain amount of technical and commercial risk. There are different philosophies when it comes to addressing this concern: (1) construction of the FOWTs in a port with subsequent transport to the offshore site (via tows) and (2) modular construction of FOWTs in the field. The former reduces the constructional risk, but transfers the risk over to the floating structure towing and moorings/cable installation operations.

Currently, all the turbines used in FOWF projects are based on fixed bottom designs. The key reason for this is that FOWFs to date have predominantly been demonstration projects with only a few of these reaching commercial operation. Also, wind turbine OEMs argue that there is no need for fundamentally new turbine designs and that technical adaptations are sufficient to deal with the changing requirements in floating.

These adaptations may vary, but tend to include the following:

- Changes to installation, maintenance & repair procedures and provisions.
- Re-programming of the control systems to enable proper compensation of sway/heave motions and dynamic loading.
- Adaptation of mechanical systems including lubrication for higher heeling angles.

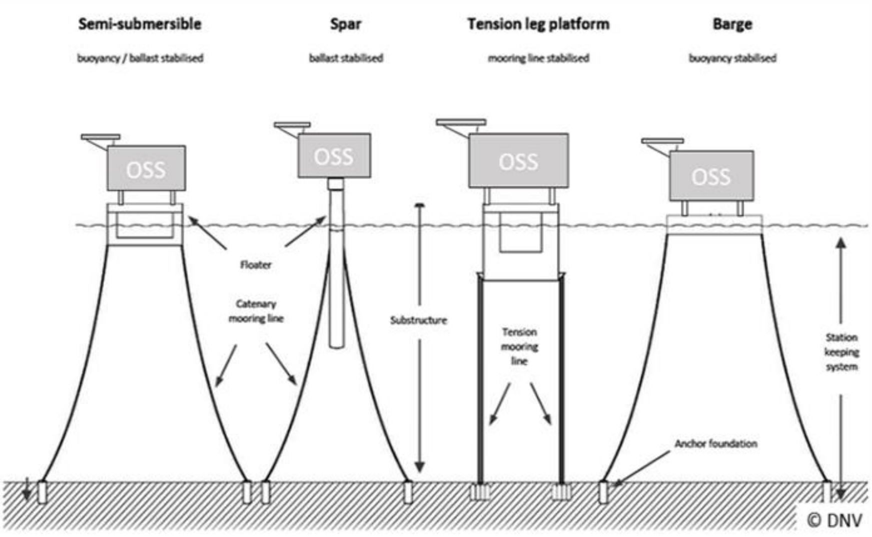
Against this background, it is likely that that design standards and modifications of FOWTs will continue to play an important role in the future. After all, FOWF projects are subject to elevated risks from higher dynamic loads compared to fixed bottom offshore designs and these will have to be managed throughout the asset lifecycle. Therefore, project certification will play a key in risk management, especially in terms of interface management. For more information, see also chapter 6. Risk Mitigation, Certification & Standards.

3.5 Floating Substation Concepts

To date, the offshore wind industry is predominantly served by fixed bottom substations. As FOWF projects reach commercial scale, floating offshore substations may be required to perform a similar function in a deeper, more dynamic marine environment. For now, floating offshore wind projects have not yet reached a scale whereby 66kV cables, suitable for inter-array use, may not also perform the export cabling function. However, with floating projects now being drawn up for upwards of 1GW, this may soon change.

Not dissimilar to FOWFs, floating offshore substations may also take on a variety of design concepts in both floater design and in mooring arrangement. In future, it may even be possible for a substation in a deep-water environment to be submerged or to rest on the seafloor.

Figure 16: Examples of Floating Substation Concepts



Source: DNV[12]

The floating offshore substation may be larger and heavier than the FOWTs of the farm that it services. With both sensitive equipment and various inter-array and export cabling entering and exiting the unit, the floating offshore substation may be particularly sensitive to excessive wave motions. Any incident relating to the floating offshore substation may also prevent the entire windfarm from feeding its electricity into the grid for a prolonged period. Therefore, it will be very important to consider the design of the floating offshore substation with station-keeping and stability characteristics in mind. For example:

- Foundation type – If the waters are just deep enough for a floating concept, the substation may nevertheless be a bottom-fixed design. Otherwise, the deeper draft designs may provide for better platform stability. Minimizing freeboard may also become a concern.

- Moorings and anchors – The tension leg mooring approach may provide for more stability than that of a standard catenary mooring system. The appropriate anchors should be chosen with the seabed soil conditions in mind. It may be important to consider redundancy in terms of not just station-keeping, but also making sure that the platform does not capsize with the loss of just one mooring cable, especially in a tension leg mooring system.

- Export cabling beyond 66kV – Whilst dynamic inter-array cabling at up to 66kV has earned a nascent track record recently, dynamic cabling at a higher voltage (128kV to 132kV, or more) remains a challenge to the industry as the traditional water barrier lead sheath underperforms and cannot sufficiently flex to the increased dynamic marine loads and motions of a floating system. The industry continues to evolve to find the best water barrier sheathing material for both high voltage and dynamic marine loading applications. Attention must also be paid to the point at which the cables join the floating substructure, as fatigue failure risk may peak at this point for both inter-array and export cables.

3.6 Floating wind and Power to X

"Power-to-X" technology (P2X or PtX) refers to various processes which turn electricity generated by renewable energy, into storable and transportable fuels, such as hydrogen, methanol or other synthetic substances. The aim of this technology is to enable the storage and use of renewable energy when it is not immediately available, therefore making the energy system more flexible and reliable.

For example, the electricity generated from a floating wind farm can be used for electrolysis to split water (H_2O) into its elements, i.e. oxygen (O_2) and hydrogen (H_2). As there are no CO_2 emissions as by products, the hydrogen generated from this process is known as "green" hydrogen.

The PtX technology and floating offshore wind power can complement each other. There are a lot of potential advantages and use cases, but the most relevant one is that FOWFs tend to be located in farshore locations which renders the transport of electricity to shore complicated. That said H2 production offshore could help save considerable CAPEX and OPEX costs associated with expensive transmission technology (e.g. HVDC) otherwise required.

Key takeaways:

- There are four primary floater design types: Spar-buoy (Spar), Tension Leg Platform (TLP), Semi-submersible and Barge. The selection of the floater type will vary depending on the location and conditions of the windfarm.
- Mooring systems play a key role in FOFWs and are subject to significant risks such as failure.
- Dynamic cable designs differ from static cable designs and come with new risks. New cable configurations are being developed.
- Floating wind turbines are subject to a wide array of new risks incl. increased dynamic loads.
- Certification is currently limited and is expected to increase significantly in the coming years.
- Floating substations are still under development, however some substations for floating projects may still be fixed bottomed.
- Power-to-X technology provides an opportunity for electricity generated by floating offshore wind farms to be stored.

4 Supply Chain & Logistics

This chapter describes the main supply chain & logistical elements related to FOWF projects during construction and operational/O&M phases. Like fixed bottom projects, the supply chain is currently under pressure. In combination with increasing labour and steel prices, it is therefore important to consider these elements carefully during the underwriting process.

4.1 Supply Chain

OEM overview and key suppliers

For each project, the relevant OEMs and key suppliers will vary greatly due to local content requirements, supply chain availability, and the extent to which local heavy industry is sufficiently developed and competitive. Today's volatile geopolitical climate adds further risks which have increased in the last couple of years. With the exception of key components such as turbines and cables, which tend to be provided by a few well-known OEMs, the supply chain for floating projects remains largely *ad hoc* and is sensitive to what is locally available and cost competitive. Therefore, for the time being floating offshore wind remains predominantly project-based, rather than commercialized as an assets-based, streamlined production process.

This is best illustrated by the floating foundation which is inherent to the project and will be heavily reliant on existing local heavy industry. The local industry may be experienced in marine and offshore construction work, but where this is not the case, local civil and onshore construction companies may also be utilized. Concrete which is used to build some Barge floater concepts is a viable option where there is local experience working with concrete and the Spar design may be an option where local harbour draughts permit it. If local heavy industry is not existent or competitive, local content requirements may clash with the economic need to have the foundations produced in an area of the world where such facilities are in place and competitive; however, this may result in an additional element of transportation risk to the assembly area which is typically located closer to the operational site. There is no set pathway here unfortunately. What works for the constraints of each project depends on the way these determinations are made. However, this results in issues concerning economies of scalewhich floating offshore wind needs to achieve in order to become more competitive.

For component manufacturers whose products are more "widget" like and off the shelf, there are often only a handful of suppliers worldwide. In addition, the experienced transport and installation (T&I) contractors are also relatively few and concentrated in Europe, with suitable installation vessel availability remaining a known issue[13]. While contractors who have historically operated in the oil and gas space are generally eager to put their tonnage to work in the renewables space, the resurgence of the offshore oil & gas industry as a matter of energy "security," will mean that there will be competition for the availability of these vessels as well. As turbine sizes and farm sizes both continue to scale up, suitable wind turbine installation vessels (WTIVs), cable-layers, anchor-handling tugs, crane barges, etc. large enough to handle the increased dimensions will remain particularly scarce. In addition, certain regions may have other local constraints, such as the Jones Act in the United States, which may necessitate an entirely new range of vessels to handle the feeder and trans-shipment responsibilities, as European WTIVs would be unable to load from a "US point."

Ports & prefabrication yards

Port availability and suitability are key during the different construction and operational phases of FOWF projects and play an essential role in the development of a reliable supply chain management system. The lack of suitable ports can be a blocker for the commercial development of offshore windfarms in certain geographical areas.

Port facilities can be divided into manufacturing and mobilization ports.

- A manufacturing port is typically located in the vicinity of offshore wind farm manufacturing facilities and is used to deploy the manufacturers' support structure and FOWT components before deploying offshore.
- Mobilization ports are used when temporary storage of equipment before deployment offshore is necessary, particularly in developing areas without an existing nearby manufacturing port.

In the case of floating projects, the port of manufacturing and mobilization could be the same for concrete platforms as they don't need a special place, as in the case of steel which typically requires adequate shipyards.

Laydown areas for mooring, anchors and dynamic cables need to be close to the offshore site too, but these can be manufactured anywhere.

Port infrastructure also determines the choice of steel or concrete. Steel can be pre-fabricated elsewhere and assembled quickly, and allows lighter structures which minimizes water depth requirements. Concrete ensures local content, doesn't need specialized welding equipment, and the raw material is low cost.

Ports need adequate water depth to allow the floating platforms and tug vessels to move the equipment and a waterway width typically over 200m to transport the rotor-hub with installed blades. The different foundation concepts all have different port requirements.

Ports should ideally be suited for foundation manufacturing at a shipyard, wet storage (including temporary moorings), blade and tower installation using cranes, laydown area for mooring lines, anchors and cables, fit-out provisions (turbine installation onto the foundation, dry dock or semi-submersible barge for load out) and O&M.

The prefabrication (ship)yard for the substructure construction could be located far from the final offshore destination but ideally the fit-out yards are as close to site as possible to minimize the tow out period(s), which are weather restricted.

During the operational phase it is equally important in relation to O&M and potential repairs to have suitable ports as close as possible in order to prevent long tow periods.

4.2 Transport & Installation

Installation concepts

Installation concepts for FOWF projects are highly linked with the floater types. The installation concept for different floater types are referenced in Chapter 3 of this paper. There is currently a lack of consensus on installation approaches, costs and time for each task for FOWFs. Similar to fixed-bottom projects, significant wave height, current and wind speed restrictions apply to all marine activities. Given that some specific floater types and installation methods (e.g. wet tows) are more sensitive to weather windows, special attention needs to be paid to suitable installation methods and equipment as well as contractor experience. This is discussed in the table below:

Figure 17: Installation concepts

Key types	Installation concept	Heavy Lift Vessel required?	Risks
Spar	- A). Turbine installation offshore - the draught is wet towed to site, followed by turbine installation. - B). Turbine installation in deep water from the quayside, and towed to the site.	Yes	- High draughts makes towing difficult. - Requires heavy lift vessel. - Unstable motion of floater during mating with turbine installation. - Tighter weather constraints. - Height requirement for port condition, sheltered waters with high depths are required near the construction sites.
Tension Leg Platform (TLP)	- TLP has low intact stability. Options for TLP installation include: - Adding temporary ballast to the hull. - Constructing offshore using a crane vessel with active heave compensation. - Using a variable draft i.e. large water plane area for float out, and after mooring tensioning, returning to a draft with low water plane area.	No	- Transit during installation is challenging due to instability. - Complex Installation requires slow and lengthy process. - Complex mooring and anchoring system.
Semi-Submersible	- Full assembly can take place onshore at quayside. - Requires only tugs and anchor handlers for towing out for mooring connection.	No	- The main challenge in the installation process is weather constraints, sensitive to wave height limits during towing.
Barge	- Due to the shallow draft assembly, this can be done onshore in a dry-dock. - Requires only tugs and anchor handlers for towing out for installation.	No	- Barge structures have a low draft, making them suitable for shallow water ports, though they have higher motions in waves.

Marine operations, such as the installation of mooring and anchoring systems, upending and mating of Spar-type platforms, towing of platforms to the location have to be carried out in calm sea conditions.

The following table demonstrates metocean limitations during assembly, transit and installation of different kinds of platforms.

Figure 18: Metocean limitations

Significant wave height (Hs)	Floater Type			
	Semi-Sub	Spar	TLP	Hybrid
Assembly		1		
Transit	2.5	5	4	3
Installation	2	2	1.5	2

Source: Significant Wave Height limitation during assembly, transit and installation - approximate values according to James and Ros (2015)[14]

Vessels

A variety of vessels are used for floating wind assets during both the installation and O&M / operational phase (e.g. heavy-lift crane vessels, towing vessels, tugs, barges, cable-lay vessels). The installation procedures differ according to the type of floater used. Generally, FOWF installation requires a greater number of vessels compared to fixed wind, but the vessels are less expensive to hire and easily available as long as there is no need for heavy lift vessels.

There are common challenges in both fixed and floating projects such as the Jones Act for US projects and the critical importance of weather windows. However, the most important common challenge remains specialized vessel availability and increasing day rates. The main risk here becomes that the party with the highest buying power gets to the front of the line.

Floating foundations are currently towed back to port for maintenance and repairs. A number of "floating-to-floating" O&M solutions are currently being developed which allow for offshore maintenance. However, the technology and vessels for undertaking major component repair and replacement have not yet been developed.

Transport

There is a key distinction between the transportation of cargoes and equipment both onshore and offshore and the final transport of the FOWT to the site for installation, hook-up, testing, commissioning..

The former scenario is the basic on-/ offshore cargo transit. This may include transit of original equipment, raw materials, and other components by truck, rail, and/or vessel, to the fabrication and/or assembly location. The exact setup can vary significantly case-by-case, especially in respect of whether the cargo is arriving from local or international suppliers. Further, to the extent that various materials and/or components may arrive at different times, proper storage facilities may also be required, protecting the materials from the elements as well as fire risk or storm surge if the facility is quayside.

The latter scenario is far more significant. This may include transit of the completed foundation to the assembly yard where the tower and turbine is waiting to be installed (in cases where the fabrication location is different from the assembly location which is usually in proximity to the final operational site), and/or the transportation of the entire assembly to the operational site. This can be done by way of a heavy-lift vessel, but is more typically achieved by wet towage. Any accident during these operations may cause the total loss of the entire turbine, plus additional costs relating to sue and labour, removal of wreck and debris.

4.3 Role of MWS

Like the certification body, the Marine Warranty Surveyor (MWS) is expected to perform a key third-party "peer review" function in respect of the construction of FOWF projects. This is particularly relevant in the floating offshore wind space where the relevant marine operations may be even more extensive for the T&I contractors. Whilst embracing some limited manufacturing surveillance duties (especially relating to the (pre-)fabrication of bespoke equipment such as foundations and cables), the bulk of the MWS verification relates to high-risk activities such as key lifts, wet towage, dry towage (heavy-lift transit), launching, cargo transport and handling, installation of cabling and/or moorings and anchors, hook up and commissioning. It should be noted that given the often novel and complex supply chains of floating projects, broader MWS involvement can be required, covering areas such as (pre)fabrication and interim storage. The Joint Natural Resource Committee (JNRC) has provided a very useful guidance in the form of JR2021-028 (subsequently updated by JR2023-029) and the corresponding JR2021-028A for insertion into WINDCAR insurance policies. This document provides two relevant scopes of work for floating projects:

- Scope of Work (SOW) 3: Floating Foundation Offshore Wind Farm
- SOW 4: Subsea Cable Installation and Shore Pull-ins for Fixed and Floating Offshore Wind Farms (inter-array and export cables)

To the extent that the construction of a floating foundation may entail fabrication works at an existing shipyard or similar facility re-purposed for floating offshore wind (e.g. yards used for constructing jackets or monopiles), the existing JH143 survey format is also very useful for the MWS to help assess the construction risk onsite and perform site visits. For heavy-lift transits and wet towages, towage surveys are also typical in the marine insurance space, wherein the MWS checks the tug, tow rope, fastenings, routing, weather windows and sea states, safe harbours along the route, etc. These tools are the best ways to help ensure that the T&I processes proceed as smoothly as possible.

With the commercial and technical evolution of FOWF projects, it is expected that SOWs and MWS involvement will continue to evolve in order to ensure best practice exchange.

Key takeaways:

- Supply chain and logistics for FOWFs are complex and highly depending on the individual project specifics and the type of the floater design.
- Whilst there are similar challenges compared to fixed-bottom projects (e.g. vessel availability), there are some increased risks to consider in floating projects, for example, wet-towages of modules and port availability.
- Proper MWS support across all high risk phases of the project (on-/ offshore)is key and it is likely that the role and scope of the MWS will continue to evolve in line with the floating industry.

5 Operations, Maintenance & Repair

In one of their latest reports, DNV believes that floating offshore wind will be commercially attractive without subsidies by 2035[15]. As FOWF projects scale up, both in terms of MW per FOWT and number of FOWTs within a single farm or development, both the O&M scenarios (in terms of planned O&M) and repair scenarios (in terms of remedial action in the wake of unexpected defects and damages) continue to gain in importance. For small demonstrators experience shows that repairs may be complicated. Form the harsher environment which drives up access cost to issues around the supply chain in terms of both infrastructure and experienced contractors, there are many factors which are likely to increase the costs of O&M and repair compared to fixed foundation wind.

FOWF projects should therefore develop clear O&M and repair plans which consider the constraints of the project location and available local infrastructure. Key questions include how to proceed with unplanned repairs and whether in-situ repairs are possible or if towage to quayside or shore is required. Accordingly, procedures and method statements need to be developed. This is particularly important to avoid unqualified repairs and to ensure that OEM warranties remain in place. That said, a thorough assessment of O&M and repair procedures against the background of OEM warranties and service and maintenance agreements (SMAs) will be key to underwriting. In addition, having a dedicated O&M team and involving the MWS as early as possible will prove valuable. This is especially relevant for smaller operators who may have limited resources .

In the following we highlight key focus areas around O&M and repair.

5.1 Infrastructure & Supply Chain

Adequate port capability and capacity is key. It is expected that there will be a significantly greater use of Service Operation Vessels (SOVs) and Crew Transfer Vessels (CTVs) to support O&M programs in FOWFs. Most existing ports should be able to support this although port congestion could present itself as a concern. Port capabilities and capacity to support the large construction phase for any given FOWF project is more uncertain due to the size and nature of the floating wind structures. Specialised infrastructure would be required for the deployment of floating structures such as Semi-submersibles, Spars and TLPs. For Spar and TLP structures, these would potentially require additional access to sheltered deep water locations close to port facilities for vertical assembly programs. Likewise for Semi-submersible structures, larger and deeper draft quays are likely to be required for the construction and assembly of these FOWF configurations.

The introduction of the much larger floating structures requires access to much larger laydown and staging areas close to and around the port facilities than currently utilized for the fixed bottom wind turbine configurations. The scale of construction of the floating structures in terms of the number of floating units for a commercial FOWF project (which can be upwards of 50 units), will be the main challenge that developers and local supply chains will need to address. This will have a major impact on the suitability of existing port locations with the potential need to identify alternative locations.

5.2 In-Situ vs. Tow to Port?

The execution of any maintenance or repair operations on a floating installation will always remain a challenge. Unlike fixed bottom wind turbine installation which remain static for any intervention, service operators will have to deal with the dynamic motions of FOWF structures often located in fairly harsh sea state conditions. This is exacerbated by the fact that the maintenance and/or repair crew could be required to work from a dynamically active platform, typically from a service or construction vessel. This is likely to limit the types of maintenance and/or repair operations to more routine and simple operations that are not sensitive to dynamic motions which can be safely executed in-situ.

More complex maintenance or repair operations which require offshore crane lifts or are sensitive to dynamic motions will likely require the entire FOWF structure to be towed back to port or to sheltered waters before the operations can be executed safely. Depending on the availability of nearby port infrastructure, such tows could pose a significant risk in themselves. Additional towage considerations may be required if the FOWF structure's buoyancy is compromised in these tow-to-port scenarios. This also has an impact on the design requirements for each individual FOWF structure, including the need for safe as well as rapid mooring and cable disconnections and reconnections.

5.3 Mooring line and dynamic cable repairs

It is likely that there will be a greater exposure to cable and auxiliary component failures due to the dynamic nature of FOWFs. Even though there is experience, including specialized technical know-how, in dealing with floating structures from the offshore upstream sector, not all of that is transferable to floating wind. Mooring failures, such as those observed with floating platforms and FPSOs in the upstream oil & gas sector, will be new loss scenarios for the offshore wind sector. However, unlike in the upstream oil & gas sector where there tend to be few large individual platforms and vessels with typically high protection and redundancy levels, FOWFs comprise many units with lower protection and redundancy levels. This poses considerable challenges for O&M as well as repair procedures and may lead to conflicts of aligning technical effectiveness and safety with commercial viability.

5.4 MWS Involvement

The workload for MWS in conducting installation reviews and approvals for offshore wind developments is likely to increase significantly in FOWFs which is driven by a variety of factors such as the increased interface risk between project assets (e.g., turbine and floater), the additional requirements around mooring systems and dynamic cables as well as potentially more complicated repair procedures involving marine operations such as wet tows. There is relevant experience for MWS from the offshore upstream sector, such as rig moves and Spar/TLP up-righting and deep water mooring installations. However, the sheer scale FOWFs, especially the large number of units and repetitive operations is likely to introduce a new dimension to the role of the MWS in O&M as well as repair scenarios. This should be considered at the MWS kick-off meeting and documented in the MWS scope of work (SOW) where possible.

Key takeaways:

- There is currently a high level of uncertainty around the nature of O&M and repair procedures in floating wind.
- Experiences and current lessons learned from the various existing global prototypical and small-scale commercial FOWFs have already highlighted the specific complexities of floating wind (e.g. the lengthy tow for repair at the Kincardine wind farm).
- Therefore, proactive engagement of all stakeholders such as developers, suppliers, manufacturers, installers, MWS, classification societies and regulatory bodies is necessary to ensure safe and efficient O&M and repair.
- Whilst there are similar challenges compared to fixed-bottom projects (e.g. vessel availability), there are some increased risks to consider in floating projects, for example, wet-towages of modules and port availability.

6 Risk Mitigation, Certification & Standards

The key for risk reduction lies within standardization based on experiences from bottom-fixed offshore, oil & gas floating structures and the maritime industry. Industry standards are developed to support innovation and bundle industry experience, to allow for efficient know-how and best practice exchange to facilitate a safe and sustainable industry growth worldwide.

Experience from the fixed offshore wind industry has shown that certification against recognized industry standards is a generally accepted way to establish stakeholder confidence and ensure bankability as well as insurability. Certification according to an accepted assessment scheme demonstrates compliance with relevant industry standards and shows that technical risks have been understood and managed across all phases of a project.

6.1 Existing standards related to floating wind applications

The table below shows the main standards with a technical focus on floating offshore windfarms (FOWFs):

Figure 19: Main standards relating to floating wind applications

Asset	Governing standards
Floating wind turbine systems (incl. towers, floaters and mooring systems)	DNV-ST-0119, IEC 61400-3-2, ABS floating offshore wind turbine (FOWT) Guide, BV NI572
(Dynamic) Inter array cable	DNV-ST-0119 sec. 16, CIGRE TB 862, DNV-ST-359, ISO 13628-5, API Spec. 17E
Floating substation	DNV-ST-0145, DNV-OS-C103, DNV-OS-E301 ISO 19904-1, ISO 19901-7, IMO MODU Code
Export cable	DNV-ST-0359, IEC 62067, IEC 60287-series, IEC 63026

Source: DNV

While some of these standards are floating specific, others are borrowed from similar technologies and have been adapted accordingly. The maturity of standards varies by the different assets:

- Floaters: For floaters a wide range of specific standards exist and are under continuous development
- Wind turbines (rotor and nacelle assembly – RNA): Wind turbines used in FOWFs are type certified for generic conditions according to IEC 61400-1 (often simply referred to as "type certification") which are subsequently adapted to the site and project specific conditions. Therefore, there is no (and probably will be no) type certification which is specific to floating offshore wind. Ultimately the combination of wind turbines and floaters will always be site and thus project specific and hence remain subject to project specific design and engineering.
- Floating substations: for floating substations there is no dedicated standard available as of today. However, standardisation is under development and a joint industry project on “Floating Offshore Substations” is ongoing. For the time being, the standard for fixed

offshore substations DNV-ST-145 is used combined with the design standard for the support structure selected DNV-OS-C102 for ship-shaped and cylindrical units, DNV-OS-C103 for semisubmersibles (column stabilized), DNV-OS-C105 for design of TLPs and DNV-OS-C106 for deep draught floating units (spar) or ISO 19904-1 for the floating structure and ISO 19901-7 for the station keeping system.

- Dynamic cables: there is no dedicated standard for dynamic cables at the time of writing this paper. Until now existing cable standards are being used and combined with standards from similar types of applications such as flexible risers and umbilicals. However, it must be noted that very limited technical experience exists with dynamic cabling (especially for power ratings above 66kV).

Against this background, the landscape of relevant standards is both dynamic and heterogenous. In the absence of type certification as known in the wind industry so far, site and project specific design remains a key challenge for the floating industry. Therefore, project certification is seen as a must when it comes to risk management.

6.2 Interface risk management & project certification

As mentioned above, FOWF projects pose significant challenges when it comes to integration of the different assets within the project. Therefore, proper interface risk management is key to reduce technical and commercial risk across all project phases from design to construction and operation.

The main certification schemes applied for floating wind farms are the DNV-SE-0422 "certification of floating wind turbines" and the DNV-SE-0190 "Project certification of wind power plants" as well as the IECRE OD-502 "Project Certification Scheme".

Figure 20: Certification Schemes

Asset	Recognized Certification Schemes
Floating wind turbine	DNV-SE-0422, IECRE-OD-502 and DNV-RU-OU512, ABS FOWT Guide, BV NI572 for class
Inter array cable	DNV-SE-0422, IECRE-OD-502 "other structures"
Floating substation	DNV-SE-0190, IECRE-OD-502 "other structures"
Export cable	DNV-SE-0190, IECRE-OD-502 "other structures"

According to these certification schemes, the key areas of project risk assessment are:

- Design assessment of entire FOWF systems: this comprises the assessment of the loads, which is performed in a coupled load analysis considering the interaction and dynamics of the rotor and power take off, the supporting structure consisting of the tower, floater and station keeping system. In the analysis the combined loads from wind, waves, currents are considered along with system aerodynamics and aeroelasticity, hydrodynamics, elasticity and the interaction with the turbine control system. The load analysis is performed in several loops by the turbine OEM and floater designer and adds an additional complexity compared to bottom-fixed structures. Therefore, the project principal often asks the certification body to validate the design and load analysis. The design assessment is performed for the final configuration of the floating wind turbine structure and may comprise several variants, depending on the clustering approach made for the wind farm (e.g. different water depths, anchor design etc.). The complete structure - RNA, tower, floater, mooring, anchors, inter array cable – with special focus on interfaces between contractors is assessed. Some developers exclude inter array cables from the project certification which is not recommend as experience has shown that cables are a leading source of claims.

- Design assessment of floaters: usually, model basin tank tests are performed in the model basin for derivation of hydrodynamic coefficients and validation of models used to investigate the overall behaviour of the structure and avoid unforeseen effects.
- Design assessment of substations: for substations a formal safety assessment is performed as well as additional tasks beyond structural integrity checks. These include fire protection, access and transfer of personnel, emergency response as well as assessment of low and high voltage equipment.
- Assessment of new technology (e.g. dynamic cables): for some novel technologies as e.g. synthetic materials, novel joints, single point mooring designs or new dynamic cable technologies where no dedicated experience and standards exist, a technology assessment is required. The goal of this is to produce a technology qualification plan. The qualification plan is assessed and describes all the measures required to qualify the technology and make it certifiable. These measures include in depth analysis, numerical simulations and laboratory or full-scale tests. This procedure is described in the DNV-SE-0422 concept certification and is often performed by the technology provider (OEM) in parallel with the concept review.
- General assessment of project risk: the execution phase comprises the fabrication, transport and installation survey as well as the commissioning of the assets. The purpose of the survey activities is to verify that the fabrication, transport and installation are carried out according to the design requirements and are in compliance with the applicable codes and standards. A risk-based verification approach is applied, which means that effort is focused on the most critical issues and items. The evaluation of what poses the highest risk is based on a combination of discussions with the developer and experience with similar projects. For large FOWF projects additional areas are assessed such as (interim) storage of components (especially wet storage).

6.3 Underwriter checklist

To be on the safe side when it comes to standards and certification, Underwriters should consider the following questions:

- Is there a project certification in place according to recognized:
    - standards and
    - certification schemes?
- Are all project assets part of the project certification?
- Is the certification body accredited? (Note: certification is not a protected term).
- Has novel technology been qualified adequately (esp. dynamic cables)?

Key takeaways:

- The landscape of standards for FOWFs is still developing as specific standards are paired with existing standards borrowed from similar technologies.
- Full project certification including all assets according to recognized standards and certification schemes is key for risk management.
- Special attention should be paid to assessment of new technology (such as dynamic cables) and interface risk management.

- Certification should be performed by an accredited body.

7 Underwriting considerations

7.1 Key Exposures for floating wind

FOWF projects are a new and rapidly developing technology in the wind energy industry. While the potential benefits of FOWF projects, such as access to higher wind speeds and deep water locations are significant, there are also several engineering risks associated with their development and deployment.

Site Conditions

Compared with bottom-fixed windfarms, FOWFs are generally located in locations with deeper water depths, greater distance to shore and therefore much harsher weather conditions. These must be taken into account not only in terms of design, but also with regard to the installation and O&M methods. Although FOWFs do not require foundations, ground conditions are decisive for the anchoring system. Appropriate site investigation campaigns must be carried out to identify those risks and mitigate them. The deployment of FOWFs can have impacts on the marine environment such as the introduction of noise pollution and the potential for collision with marine wildlife. Careful environmental assessments must be conducted before the deployment of FOWFs and mitigation measures must be put into place to minimize these impacts.

Design Maturity

The floating foundation structures must be designed to withstand harsh weather conditions, including high winds, waves, and storms. There are more than 40 floating wind concepts at the moment and new designs are frequently announced[16]. This suggests that at this point in time there is a lack of unified design standards and guidelines. According to Norway's Marine Energy Test Centre (MET Centre), a leading test body to provide site and facility tests for floating wind concepts, many floater designs have not been tested yet and there is a lack of testing resources and suitable facilities[17]. As identified by ORE Catapult, a renowned research body in offshore renewables, there are several governing floating wind standards available, but gaps and differences have been observed between different standards, especially for certain novel concept configurations[18]. Detailed discussions on standards are presented in chapter 6. Risk Mitigation, Certification & Standards. Ultimately mooring systems, dynamic cables, cable protection systems and electrical connections (either flexible or rigid) must be reliable and must be able to withstand harsh weather conditions for their predicted effective lifespan. Hence full project certification as per recognized standards, i.e. IECRE OD-502 and DNVGL-SE-0190, including cable and substations packages, is considered one of the risk mitigation tools to ensure designs are fit for the purpose.

Manufacture, Assembly and Installation

Manufacturing and assembling large commercial scaled FOWFs will be demanding as it requires suitable pre-assembly and port facilities. Some concepts require deep water installation and large laydown areas. Although, comparing with bottom-fixed wind farms, significant portions of the installation process for FOWFs can take place onshore, the offshore tow and installation process will be more complex and riskier.

Grid Connection

FOWFs must be connected to the electrical grid for the generated power to be transmitted to shore. This requires the development of reliable electrical interconnection systems, which can be challenging due to the remote location of the FOWFs and the harsh offshore environment. The risks related to dynamic cables as well as floating substations are discussed in Chapter 3. Floating Wind Technology.

Repair and Maintenance

FOWFs are often located in farshore locations, which inhibit access and can be challenging for maintenance and repair operations. The design of the FOWFs must allow for access to all parts of the system for maintenance and repair, and the necessary equipment and personnel must be readily available for these operations. The same applies for port infrastructure and other sites as required. More specific risks are explained in the dedicated chapter 5. Operations, Maintenance & Repair.

Logistics and Supply Chain

The logistics of deploying FOWFs can be challenging due to the offshore location and the need for specialized equipment and personnel. This includes the transport of components, materials, and personnel to the site, as well as the installation and commissioning of the FOWF. All of which can be a challenge in FOWF projects.

In conclusion, the development of FOWFs presents several engineering risks, including technical reliability of floaters, turbines, mooring and anchoring systems as well as issues around maintenance and repair, environmental impact and high costs for grid connection and logistics. Careful design, planning, and management are required to mitigate these risks and secure the success of FOWF projects. Also, project certification is seen as a must for FOWFs.

7.2 Underwriting best practice & wording considerations

This section of the paper will discuss the best practices in drafting wordings to address some of the key coverage and claims challenges that underwriters will face around FOWFs.

Serial Loss Clause (SLC)

As can be seen in chapter 3. Floating Wind Technology, the design, materials and workmanship used in the floating structures, dynamic cables and mooring systems are still in their infancy. Accordingly, they are unproven and long-term validation is required. Dynamic loads imposed on turbines and cables are new challenges to the operating environment that floating offshore wind turbines (FOWTs) are subjected to on a daily basis. The potential inability of cables and other equipment such as main components to resist premature fatigue is driving significant serial loss exposure.

There are varying versions of SLCs ranging from standard wordings, such as the one drafted for onshore renewable projects by the Lloyds Market Association (LMA5587), to less restrictive broker manuscript SLCs. Against this background Underwriters must pay close attention to exact SLC wordings.

The following points may serve as a check list to ensure that manuscript SLCs contain key safety provisions and limit series loss exposure effectively:

1. Does the SLC apply to all insured property or only to specific components?

   To limit series loss exposure effectively, the SLC should ideally apply to all property insured or at least the critical components such as: FOWTs (towers, nacelles and blades), dynamic cables as well as mooring systems and floaters.

2. How does the deductible apply and is there any deductible aggregation?

   Some manuscripts scale deductible application according to the indemnity scale which obviously provides less protection and seeks to balance deductible application and indemnity.

Attention should be paid to any form of deductible aggregation (e.g. the deductible applies "once per root cause" or "once per occurrence"). This is clearly the widest form of cover.

3. Is the defects language of the SLC aligned with the defects cover of the policy?

   This is an important point to consider since in case the SLC applies to a narrower set of perils than the defect clause. If the SLC is wider than the defect clause then this could be misconstrued to broaden defects cover otherwise excluded under the policy.

4. Is the scale reasonable?

   Depending on the number of wind turbines and other serial components a reasonable scale should be identified.

5. Does the SLC also apply to curtail DSU/BI losses?

   To provide a maximum level of protection, SLCs are often re-copied from the PD to the DSU/BI section. As regards the indemnity scale a reasonable level of curtailment should be considered.

Design Clauses

Losses arising from defects in design material workmanship plan or specification are often contentious and challenging in practical claims situations. Often the difficulties in making a clear-cut distinction between defects and physical damage, as well as differing legal interpretation in different jurisdictions adds to the contentious nature of defects claims. The most commonly seen design exclusions are those detailed on the website of the London Engineering Group (LEG).

Underwriters should give due consideration to the largely unproven components in FOWFs and the associated risk level before defining an appropriate design exclusion.

There are robust experiences with the implementation of LEG clauses to mitigate technology risk in the onshore & offshore wind market and it sensible that FOWFs are treated accordingly. LEG1 is the most restrictive cover, excluding all damage caused by defects. LEG2 is somewhat wider, providing cover for consequential damage but not for the cost of remedying defects. LEG3 is the broadest cover, providing cover for all damage caused by defects and only excluding betterment. In considering which design clause to apply to FOWFs, underwriters may wish to consider questions such as whether the technology in question is type certified and the number of operating hours it has been used for without incidents.

Underwriters can grant different design exclusions for different packages or components of the project. They can also choose to impose sub-limits on LEG2 and LEG3 coverage as appropriate to further control the risk level. It is worth mentioning that apart from the technology risk due to prototypical/ unproven equipment, FOWFs are facing crucial challenges when it comes to the application of LEG clauses:

1. Issues related to burden of proof

   Even when restricted cover is provided (LEG1), underwriters must always be aware that in some instances (e.g. in case of a total loss of a FOWT due to sinking), the actual application of the design exclusion might be cumbersome given the burden of proof which lies with insurers. In the event of sinking in deep waters it may be impossible to conduct a proper root cause analysis (RCA) and insurers may not be able to prove that the sinking was caused by a defect. Therefore, the claim may be challenged especially if there are other contributing factors at play.

2. Issues related to consequential loss

   The "floating" nature of FOWFs could cause challenges regarding consequential losses. For instance, in situations where a defective manufacturing process results in premature failure of the floating structures and the consequential sinking of the floating wind turbines. In this case, the financial differences between LEG1 and LEG2 could be considerable. Under LEG 1 the loss would likely be excluded, while LEG 2 would cover the consequential loss to the turbines. The same applies if we consider another scenario in which defective design of the mooring systems results in FOWTs losing position. The consequential damage to the dynamic cable systems would be significant and further impact damage to other FOWTs as well as the offshore substation could result in a very costly claim situation which would be totally excluded under LEG 1, but partially covered under LEG 2.

Apart from the LEG clauses, there is also WELCAR 2001 Defective Parts (condition 7). The standard WELCAR wording distinguishes between damage caused by a defective part (which is covered) and damage to the defective part itself (which is not), while LEG 2 on the other hand tries to achieve a similar outcome but by distinguishing the different elements on a time basis. This difference in language means that WELCAR 2001 Defective Parts (condition 7) is more closely aligned to the DE3 Wording than with LEG2. The main challenge in WELCAR 2001 Defective Parts (condition 7) is that it raises the thorny issue of what constitutes a "defective part" and how it should be distinguished from the remainder of the insured property. There is often no easy answer to this question, and it must be determined based on the nature of the defect in each instance and the circumstance leading to the damage.

Occurrence definition

Underwriters should pay attention to the occurrence definition in the policy to avoid situations in which key provisions of the policy such as the series loss clause (SLC) are potentially circumvented. The term "Occurrence" is an important definition in the policy wording as it is usually referenced in a variety of sections from the definition of "damage" to the operating clause to the application of deductibles as well as policy extensions/ sub-limits and in the context of "72 hours" provision. Hence any changes made to this section will have significant implications throughout the policy.

Deductible application

Many offshore wind policies include specific deductibles for different assets (e.g., for cables, foundations and wind turbines). However, they also may contain specific provisions in respect of works carried out "onshore" and "offshore" or involve specific deductibles for "transport". This can be problematic if these terms are not defined. Blending deductible language related to assets with project phases and or locations is especially problematic when it comes to FOWFs. This is because their logistical setup as well as their supply chains are not as standardized and well understood as fixed foundation offshore wind projects. In fact, one of the claimed economic benefits of FOWFs is that they can be built in a more industrialized fashion which means that works otherwise carried out "offshore" are moved to ports "onshore". The latter may involve pre-fabrication and risky tasks such as heavy lifts and hence the "onshore" deductibles may have to be reviewed in the scope of the respective project. The same applies for transportation which may involve higher values and be much riskier (e.g., wet tow of a fully assembled floating turbine) than in fixed foundation offshore wind projects.

Stand-by Charges and Wait-on-Weather Limits

Underwriters should consider the unique situation of floating offshore projects where the erection of the whole FOWT structure can be carried out in namely two ways:

- Wind turbine and floating structures are fully fabricated in a dry/wet dock and towed to final position; or
- Floating structures are fabricated separately and towed to their final position for the wind turbine installation to take place offshore.

In the former case, the marine transit and final positioning is considerably more challenging and subject to much tighter weather windows. In general, FOWT installation is much more dependent on good weather conditions and there are shorter weather windows available compared to fixed-bottom offshore wind. This is often exacerbated by the fact that FOWFs are located in farshore locations with high wind speeds and relative wave height.

Accordingly, underwriters should consider the increased exposure of offering Stand-by Charges or Wait-on-Weather extensions and define appropriate sub-limits. Once bound they should pay attention to the criteria for weather windows by consulting with the project MWS and other experts.

Minor Works

Minor Works clauses are common policy extension to allow contractors to carry out residual and/or maintenance work, alterations or repairs to the property insured following physical loss or damage. However, it is good practice to ensure that appropriate sub-limits are in place. The wording should also contain provisions to prevent unintended coverage for works relating to newly built projects.

Contractors and OEM Warranties / Service and Maintenance Agreements (SMAs)

As detailed above, the dynamic cable systems, mooring systems and floating structures are currently at an early stage of development and as such contractors and original equipment manufacturers (**OEMs**) may be expected to have more stake in risk sharing. As a consequence, underwriters should understand the scope of any OEM warranties and guarantees or Service and Maintenance Agreements (**SMAs**) for projects in operation and their practical implications on the cover. This can be achieved by asking the following questions:

- For which project components are warranties/ guarantees (or SMAs) in place and for how long?
- From which point in time do warranties/ guarantees attach and how is this point time defined?
- Is it understood that warranties/ guarantees (or SMAs) shall remain primary to any insurance cover?
- What is the scope of the warranties/ guarantees (or the SMA) and do they include costs for logistics?
- Are there any relevant liability caps?
- In case of DSU/ ALoP or BI, is there any availability guarantee and how is it defined?
- In case insurers advance payments, is claims recovery contractually possible?

Project handover and commercial operation date (COD)

Typically, project handover is defined in the EPCI contract, which underwriters should seek to obtain and understand. Often the expected handover date or dates in the project schedule dependent on the terms and structure of the Power Purchase Agreement (**PPA**). Underwriters should obtain details of the commercial structure of the PPA and consider if the proposed slip and wording is fit for purpose and in line with PPA. A FOWF can have a single commercial operation date if the PPA is structured that way and all revenues of the whole wind farm are meant to commence with a single milestone date. However, this is uncommon for FOWF, which may have two to three distinct phases, leading to two or three separate Commercial Operation Dates (**CODs**). These then represent the potential DSU trigger dates. Consequently, the DSU Insured Interest, Sums Insured and CODs are corresponding to each of the distinct phase(s) which must be clearly documented in the policy wording. Separate DSU time deductibles should ideally apply separately for each phase.

There are projects where each of the wind turbines may have a separate handover date. Effectively they will come online and connect to the grid upon successful completion of testing and commissioning. Typically, the estimated COD of each wind turbine will be documented in an appendix attaching to the slip, which details the wind turbine number, location in the wind farm and projected handover date. The appendix is regularly updated as part of a regular project progress update or DSU monitoring program. It is important that any extension of the project COD (or any CODs for phases or individual wind turbine) is agreed by the insurers case by case to reflect the increased DSU risks.

Maintenance Provisions

Since many of the components like floating structures and dynamic cables are still prototypical or unproven, Guarantee Maintenance (GM) is fairly rare. Typically, Extended Maintenance (EM) is the most requested cover for floating offshore wind projects. Under EM cover, cover is not wider than specified elsewhere in the policy and is given for physical loss or damage resulting from or attributable to:

- faulty or defective workmanship, construction, material or design arising from a cause occurring at the Project Location prior to the commencement of the maintenance period (“Extended Maintenance”); and
- operations carried out by Other Insureds during the maintenance period(s) for the purpose of complying with their obligations in respect of maintenance or the making good of defects as may be referred to in the conditions of contract, or by any other visits to the site necessarily incurred to comply with qualifications to the acceptance certificate.

Even though the concept of EM is widely used in the offshore wind market, specific attention should be paid to the use of EM on floating projects. We highlight a number of relevant issues:

1. Clear understanding and definition of project location

   The term "Project Location" is central to EM cover. Under normal circumstances the project location is defined as the construction site. In the offshore market this is typically broadened to include transport to the offshore site as well as works on pre-assembly sites or marshalling harbours. Given that logistics and supply chains of floating projects continue to emerge, close attention must be paid to the definition of project location as well as the nature of the works performed "onsite". If definitions are broadened or if manufacturing or pre-fabrication sites are included in the cover, this could serve to broaden the EM cover.

2. Maintenance cover is not standard in every market

   Underwriters should be aware that maintenance cover is very rare in certain markets (for example the US market). In the case of the US market this is due to liability issues, but other markets may have their own implications depending on the local law and jurisdiction.

3. Defects language should be aligned

   Since FOWF may contain full defect exclusions such as LEG 1, it is important that the maintenance cover is aligned with the defects language. Therefore, it should be clarified that Maintenance cover is "no wider than contained elsewhere in the policy".

Local insurance requirements (non-admitted insurance)

As FOWF projects are leaving the pilot stage and are scaling up, their supply chains are likely to become more globalized. Depending on the scope of cover and the territorial limits of the policy, cover may be required for works in countries with local insurance requirements. Therefore, underwriters should carefully consider local insurance requirements when including pre-assembly and/or pre-fabrication sites in foreign countries.

Removal Of Wreck

FOWTs (including the floating structures) are at risk of sinking following severe damage events such as storms. It is therefore important that underwriters understand the local and international maritime laws that may apply in event of the floating wind turbine sinking. What are the legal obligations that are imposed on the policy holder and ultimately the insurers in a sinking event? According to some offshore regulation (e.g. BSH-standard in Germany), any sunk property has to be removed in its entirety which can be extremely costly.

Against this background underwriters need to appreciate the higher cost involved in removing a sunken turbine including structure compared to a fixed bottom wind turbine. The complete wind turbine and structure may be too large for single lift and may have to be dismantled at the seabed or a special heavy lift vessel may be required which will drive up costs. Underwriters should ensure that reasonable sub-limits are in place. Careful thought should be given to any form of liability cover especially if additional costs of decontamination or nullifying environmental impact as well as any penalties or fines for pollution are included.

Marine Warranty Survey (MWS) Provisions

Underwriters should understand the background behind MWS provisions which are now a cornerstone to helping insurers to manage their exposure in the offshore wind sector. Whilst there are many experienced MWSs in the wind industry, the current rapid development of offshore wind resources means that there is ever greater pressure on MWS service providers and consultancies which may lead to the use of less experienced resources. To uphold the minimum MWS standards in the industry, under JR2021-028A the MWS should either be qualified by the Society of Offshore Marine Warranty Surveyors (SOMWS) or have completed JR2019-009 (which is an alternative means of demonstrating competence). This requirement will ensure that the appointed MWS has the right experience and expertise for the task at hand. This is an important consideration for FOWTs due to the new technology topics mentioned above. In light of unproven designs and new installation methods, the risk of insufficient MWS experience is considered high.

Therefore, the Joint Natural Resources Committee (previously JRC) published JR2021-028A Renewables Warranty Endorsement. There is no separate standard for floating offshore wind projects, but reference is made to floating projects as part of the separate document JR2023-029 Renewables COP SOW COA which covers the code of practice (COP) and scope of work (SOW) for different types of offshore wind projects.

Underwriters should ensure that the JR2021-028A is incorporated in the policy wording and that references are made to the COP as well as a detailed scope of work (SoW). Ideally these should be documented either in the policy wording or an appendix and reflect the risks and specific requirements of the project. On this note, it should not be forgotten that MWS SoWs may need to be broadened to effectively manage risks related complex logistics and supply chains. Underwriters should organize appropriate kick off meetings and follow up on the performance of the MWS throughout the project period via monthly reports and regular meetings.

Cable Protection System (CPS)

As discussed in Chapter 3. Floating Wind Technology, the design of the Cable Protection System (CPS) for FOWTs are different to the CPS designed for fixed bottom wind turbines. This is a relatively new area of development and underwriters should adopt the same cautious risk assessment approach in dealing with CPS for FOWTs. There are standard industry exclusion clauses like JR2022-034 JR Cable Protection Clause that Underwriters can consider to avoid exposure to prototypical and unproven CPSs.

Pre-Fabrication Exposure

Fabrication of floating structures and turbines is a relatively new field and underwriters should pay special attention to the experience and track record of potential fabrication workshops. The project certification should cover the quality control and certification aspects of any "offsite" fabrication workshops. The MWS should be involved wherever reasonable. Local insurance requirements must be always considered in order to avoid non-admitted insurance.

Third Party Liability (TPL)

There are four primary TPL exposures that are unique to floating offshore wind projects:

- In the event of failure of the floating structure, the FOWTs may sink and pose a hazard to marine vessels. In certain jurisdictions there are strict laws concerning pollution and removal of wrecks, therefore the Underwriter should be aware of the local and international maritime laws that may govern any sinking risk of the offshore wind turbine, including any other policy coverages for pollution and decontamination.
- The FOWTs may drift uncontrollably due to failure of securing cables during towage and/or post failure of mooring systems. In either case the FOWTs adrift uncontrollably may collide into third party marine vessels, other wind turbines or offshore assets. The financial impacts of such collisions can be significant.
- There may be contingent Marine Liability from the deployment of tow boats for positioning the FOWTs. Underwriters should carefully assess any potential buyback or extension to cover Marine Liability which may have vastly different legal meanings and exposure depending on law and jurisdiction. It should always be clarified that other Liability insurance is primary to the TPL.
- The Law and Jurisdiction consideration is an important factor in the risk assessment of TPL exposure for FOWTs.

7.3 Loss Expectancies: PML/EML Considerations

Possible Maximum Loss (PML) / Estimated Maximum Loss (EML) expectancy considerations are key for adequate pricing and underwriting of FOWFs. Various definitions exist across the insurance industry, but for the purpose of this chapter the following definition is applied:

"An estimation of the maximum loss, which could be sustained considered to be within the realms of probability, excluding losses which may be possible but which remain highly unlikely."

EML exposures vary across the different phases of a project. Large parts of the construction phase are characterized by lower build-up in values (CAPEX), but lack of protection and safety systems due to the unfinished state of the project. Values typically peak during transportation (which in floating wind is also relevant for repairs), testing and commissioning as well as during the operational phase which ultimately drives EML exposure.

EML scenarios depend on technological features such as floater design (see Chapter 3. Floating Wind Technology) and usually involve the loss of one or more complete floating foundations including the turbines, loss to cables and/or substations.

As the floating offshore wind sector is gradually moving from demonstrator projects towards full commercial scale projects, the project size and layout are determining the EML scenarios:

- Demonstrator/Test Projects of (2-10 floating WTG´s) are directly connected to an onshore substation via inter array export cable systems and do not include an offshore substation.
- Full commercial scale projects (above 10 floating WTG's) are connected to a floating offshore HVAC or HVDC substation (FOSS) via one or more export cable systems to the onshore substation. FOSS have a high concentration of CAPEX value and hence are driving EML scenarios. Depending on the project layout, FOSS are also bottlenecks. In case projects involve DSU/BI the governing EML scenario, will most likely be a fire/collision/sinking of the FOSS with consequential DSU/BI for the full indemnity period stated in the policy.

As the EML remains specific to the technical and commercial setup of individual projects, a case-by-case analysis is required. The following considerations should serve as guidance for assessing EML risks.

Operational EML scenarios:

- FOWTs or FOSSs being on fire, or sinking, or serial losses in relation to the same.
- Whilst a certain level of experience has been built-up via demonstrator projects in the floating sector, technology risk remains high due to the larger variety and complexity of design specifics for individual projects. Against this background, it must be acknowledged that proven fleet leaders with a sufficient amount of successful operating hours do not exist at the time of writing this paper. Therefore, floating technology remains mostly prototypical/ unproven which means that cover for faulty design/material/workmanship must be assessed carefully. Serial loss clauses (SLCs) may be considered to limit coverage for faulty design /material /workmanship.
- Mooring systems provide station keeping for FOWTs, by keeping the translational motions in surge & sway and the rotational motions in yaw within the specified limits. Failure of the mooring system can lead to a total loss of the floating turbine. In a shared mooring system, mooring lines can be inter-connected instead of connecting to the sea-bed for cost saving purposes. This however increases the displacements of the floaters and one of the main challenges of this shared mooring system is the reduced system reliability. Failure of the multi-line system components can cause a larger number of foundations to detach and stay adrift.

EML scenarios during transportation & marine operations:

- Key scenarios are the potential sinking of entire FOWTs and floaters or FOSSs (or parts thereof), impact during T&I.
- The marine operations vary according to the type of floater used. As wind speed and wave heights are directly related, the installation, transportation and O&M of a floating wind turbine are more challenging compared to a fixed bottom wind turbines.
- There is a basic onshore and offshore transit during construction by truck, rail, and/or vessel but the final transport of the FOWT to its final offshore destination is considered as a critical scenario. The FOWTs are on some occasions assembled in a quayside or yard onshore following which the assembled components are typically wet towed to their final destination for installation,

hook-up, testing and commissioning. The risk will vary greatly driven by towage distance and whether the operational location is considered nearshore or a far shore location.

- Especially in case of a weather unrestricted towage (marine operations above 96 hours), weather forecasts are not sufficiently reliable. Continuous monitoring and statistical extremes of metocean conditions (combined wind, wave and climate) must be considered for planning such an operation and EML evaluation. These unrestricted towing operations can take place both during the construction phase but also during the operational O&M phase when the floating foundations need to be towed back to a far-away port for repair or exchange of major items (and hence no floating-to-floating offshore O&M solution exist). The Uunderwriters should foresee provisions that damage during such complicated marine operations are not covered automatically under the operational policy and can only be accepted by the Underwriter after receiving full technical information and based on adequate terms and conditions. The longer tow increases both the potential PD loss value and resulting BI downtime loss which needs to be taken into consideration when calculating the EML value.

External EML scenarios:

- Key scenarios are sinking and vessel impact.
- These are mainly driven by NATCAT / extreme weather conditions. This is obviously the case for regions known for NATCAT events such as Japan, Taiwan and the United States, but also for projects in Europe. Extreme weather conditions need to be considered as they can cause damage even in cases where the design limits for the floaters and turbines are not exceeded (especially in farshore projects).
- For full commercial size projects, a potential EML scenario should be considered during storage on the construction / pre-assembling site, especially around the storage area, in case components are stored / pre-fabricated during the same period (e.g. flood/fire).
- Ship-collision can be a potential EML scenario depending on shipping routes/vessel traffic. This can be exacerbated where turbines lose their position due to failures of mooring systems as well as during transport, installation or repair.

EML checklist:

As a general guidance for EML evaluation the following aspects should be considered. Note that this focusses on property damage (PD):

- Floater design including mooring line designs and redundancies.
- FOWT Type and interfaces between Floater and FOWT.
- Project certification schemes and design specs for wind, currents below sea level and wave heights.
- Will a shared mooring system be used without redundancies?
- Will repairs of main FOWT components and the floater require a tow to harbour or can repairs be executed offshore? Are harbours nearby sufficiently equipped?
- Site specific concerns, like NATCAT exposure, weather conditions and windows as well as seabed structure and vessel traffic.
- Business Continuity Plan availability (e.g., typhoon preparedness plan / detailed 'what do to' when a heavy storm is forecast).

Specific full commercial scale projects

- Will one or two FOSSs be installed (i.e., is there redundancy)?
- Potential accumulation of components at the construction/pre-fabrication/storage site (flood, fire, earthquake).

Key takeaways:

- Key exposures are: site conditions, design maturity, manufacturing processes, installation methods, grid connection setup; repair and maintenance plans as well as and logistics and supply chain specifics.
- Key wordings to consider are: series loss clauses (SLCs), design exclusions, occurrence definitions, deductibles, stand-by & wait on weather limits, minor works clauses, contractor warranties & maintenance provisions, removal of wreck and MWS provisions.
- Underwriters should seek copies of EPC / EPIC contracts, PPAs and ancillary documents at an early stage.
- EML expectancy considerations are varied.

8 Coverage & Claims

8.1 Claims issues relating to novel design concepts

Many floating offshore windfarm (**FOWF**) projects are likely to use existing turbine models as the basis of their design. However, whilst turbine models themselves may not be new, there are likely to be certain aspects of the floating structure which will be new. In Chapter 3. Floating Wind Technology, it is noted there are at least four design concepts being used for floating projects at the time of publication of this paper (namely, Spar, Semi-submersible, TLP and Barge).

There are also new interface designs in FOWF projects, for example, between the turbine itself and the "floating" element as well between the floater and the cables. By their very nature, these risks are new.

As the floating design concepts are improved, it may be the case that certain designs become favoured by contractors and operators. This may mean that certain designs being used now may become obsolete, or partially obsolete. This may create challenges at the claims stage if only certain contractors are able to remedy issues arising on particular projects. It may also be the case that the manufacture of certain components may become more restricted for certain designs.

Accordingly, the following issues may arise:

- For certain floating design concepts, the non-availability of components for like-for-like repairs.
- A limited manufacture or contractor pool for components is also relevant. In particular, for foundation designs and in floating export cables.
- A limited contractor pool for redesign purposes for existing designs. Here, we can draw a comparison with fixed bottom turbines where the industry should begin to see the end of a "trial-and-error" period for design and (hopefully) fewer design issues.
- Potential manufacturer or contractor insolvency.
- Suitability issues of ports and other repair sites, in particular in terms of scale. By way of example, for large Spar type designs, there are only a limited number of ports and repair facilities that are big enough to be able to handle direct repairs to a Spar type design.

The issues listed above may specifically affect claims in the following way:

- Increased cost of repairs.
- Increased BI exposure, in particular where there is a lack of availability of components, contractors or repair yard availability / space.
- Potential betterment issues, in the event that repairs must be conducted to improved or modified design criteria.
- An inability for an insured to rely on contractor warranties.
- In a worst-case scenario, the only remedy available may be the redesign of the entire floating methodology.

Even in scenarios that are not "worst-case", there are certain elements that may be susceptible to design issues. These include:

- Cable hang-off systems – which may be designed as "weak-link" connectors. Weak-link cabling systems are designed to disconnect at certain extreme axial loads such as during an allision or during contact with an iceberg to "save" other property. They have been common for flowlines in oil and gas projects but are relatively new for cables in offshore wind projects. Such weak-link connectors might also be used as grid connectors. A question that may arise in circumstances where weak-links are designed to "break" is whether a break at the point at which the weak-link is designed to break is physical damage at all. Of course, the type of disconnection and what caused it (as well as the law of the policy) will be relevant considerations for any claim of this nature.

- Mooring lines. Whilst these systems themselves might not be new technology, they are new when incorporated into a power generating floating windfarm and at increased water depths. It is inevitable that some modifications to these systems will be required and for the technology to develop over time. Part of this will be learnt from claims experience.

- Insufficient design studies when pairing floating offshore wind turbines (FOWTs) and floaters. As described in Chapter 3. Floating Wind Technology, FOWTs and cables are likely to be subject to increased dynamic loads resulting from floater movements. There is currently relatively little experience as to how this will affect the asset lifecycle over time, but it is safe to say that further research is required and that best practices concerning FOWT suitability for particular floater types and locations should be established.

For any of the issues raised above, a careful analysis of the basis of cover and any specialist exclusions and / or conditions will need to be considered, each on a case-by-case basis.

8.2 Inspection protocols / O&M generally

As discussed in earlier sections of this paper, there is no uniform inspection protocol for floating FOWTs. At the claims stage, an investigation into the service inspection intervals may become a routine part of the claims process. However, it is vital that underwriters and risk engineers are then advised of inspection protocol issues that may arise on any given claim so that operational and underwriting standards can be improved as part of a positive feedback loop. There will of course be an inevitable tension between operators seeking to adopt less conservative inspection protocols and underwriters seeking more conservative inspection protocols.

8.3 Traditional exclusions in the new floating wind environment

As noted in earlier sections of this paper, it is anticipated that one of the challenges encountered with floating offshore structures is their ability to withstand dynamic marine environments. Whilst this is not a new risk in the context of fixed turbines, it is likely that the FOWTs will encounter greater movements attributed to the marine environment. It is also likely that FOWTs will face greater dynamic movements than other floating offshore structures in the oil and gas industry. This is because it is the very movement of FOWTs that will be used to generate power, rather than being used for material extraction.

For the FOWT itself, it is generally understood that this will result in:

- More accelerated deterioration of bearings;

- More accelerated deterioration in housings; and

- Potentially more accelerated deterioration in planetary gearboxes.

Whilst some components that are part of a fixed offshore wind project are subject to dynamic movements (most notable cables and cable hang-off systems), the turbines themselves are not usually subject to dynamic movements in a fixed foundation turbine. Therefore, it is possible that fatigue lives of existing turbine designs may be shortened.

With the above being the case, it will be necessary at the claims stage to consider what type of exclusions have been incorporated into the policy. If only traditional exclusions have been incorporated (say, for "wear and tear" or "gradual deterioration") then a careful consideration of the technical evidence along with requisite legal advice in the relevant jurisdiction will be necessary. If specific exclusions are incorporated for particular deterioration in a marine environment, then that may in turn provide clarity at the claims stage. One important point to note here is that the applicable law of the policy may alter the coverage position significantly. For example, under English law there is recent case law on the specific meaning of gradual deterioration and on the inevitability of loss. Under some exclusions, there is also the familiar question arising in relation to consequential damage to other "parts".

As turbines move ever further out to sea there will be a greater focus on the potential overlap with marine risks, particularly in circumstances where wordings for FOWTs have been adapted from onshore property insurance wordings as opposed to from traditional offshore wordings.

Under English law, most insurances on the hull of a commercial vessel are based on marine institute clauses which are on a named peril basis. This contrasts with the insurance of wind turbines which are usually insured on an all-risks basis. Under a marine hull policy, a loss caused by "perils of the sea", (which in England broadly means fortuitous accidents or casualties of the seas, but not the ordinary action of the wind or the waves) is explicitly covered.

Underwriters of FOWTs may not wish to provide coverage for the ordinary action of the wind or the waves either. However, given that "perils of the seas" in a marine policy brings with it hundreds of years of case law and statutory definition (in England at least), it may be necessary for commercial insurers of FOWTs to consider this issue more carefully if the marine environment creates perils of the seas type issues. Claims experience will also be vital for the refinement of wordings in this area.

8.4 Towage and other marine risks

One of the publicized benefits to FOWTs is that repair costs might be lower in circumstances where an entire turbine could be towed to a repair site. This is in contrast to fixed offshore turbines which require repairs to be conducted by specialist offshore support vessels. We have discussed above the concerns over port size and availability. However, there are two aspects to towage that could also be particularly relevant:

(a) Under a Construction All Risks (**CAR**) policy, the tow of an entire turbine is likely to fall within the CAR cover as part of the planned construction campaign. However, towing an entire turbine is likely to present a number of difficulties that are not present in transporting unassembled components to a construction site. In addition, where Delay in Start-Up (**DSU**) cover is also provided, this may cause an increased risk in a DSU trigger occurring.

(b) Under an Operators All Risks (**OAR**) policy, the question of the reasonable cost of repair may usually include marine spread costs. However, where a damaged turbine is being transported to a repair site, this presents a very different risk profile and it is likely that a specific (and additional) marine voyage policy will be required to cover the turbinie from the risks of the voyage. Communication at the claims stage will be vital to ensure that any potential liabilities arising from towage or transportation costs can be satisfactorily assessed and apportioned.

Another aspect that is relevant to marine risks and towing are issues such as port blockages and the effect this might have on Business Interruption (**BI**). This issue might be indirectly relevant for fixed turbines if, say, specialist vessels are unable to collect supplies but in such cases it is supply to the turbines that must be managed. Where repair to a FOWT requires access to ports and repair facilities for the turbine itself, access to and from such ports becomes directly relevant.

8.5 Protection & Indemnity (P&I) risks

Most insurers of FOWF projects will be aware of P&I cover that is available to contractors involved in the construction or maintenance of floating offshore wind projects under a “specialist operations extension” to traditional P&I cover. This provides third party liability cover for vessels operating at a wind farm (that is to say, third party liability cover to third parties). However, such cover does not extend to cover loss or damage to the contract works.

P&I cover generally provides third party liability cover for death or personal injury, and damage to third party property which arises from shipping operations. It also includes third party cover for *inter alia* collisions, pollution and wreck removal. Whilst sub-limited wreck removal cover is often included under the windfarm project’s commercial policies, one additional risk of FOWTs is the possibility of the FOWTs becoming un-moored and causing damage to commercial vessels or to other third-party property. Such collision damage may be considered remote, but as FOWF projects expand this may be an area of consideration, particularly if tugs are not immediately available to bring un-moored FOWT’s under control. Assuming a worst-case scenario where a FOWT becomes un-moored and risks causing damage to third party property, such a scenario would also increase the risk of damage to the FOFT itself and thus property insurers should at least be mindful of these potential risks. It may require quick decisions to be made when insurers are alerted to such issues at the claims stage.

Key takeaways:

- FOWFs come with plenty of novel technology which is likely to increase risk and create specific claims issues. It could also increase claims costs.
- Inspection protocols discovered at the claims stage should be fed-back to underwriters as appropriate so a better understanding of certification can be developed.
- Traditional exclusions are likely to be tested. Other exclusions for the marine environment may be required in future. Towage provides opportunities but it also presents its own risks. Third party liability may be tested in future. Emergency response may be critical.

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