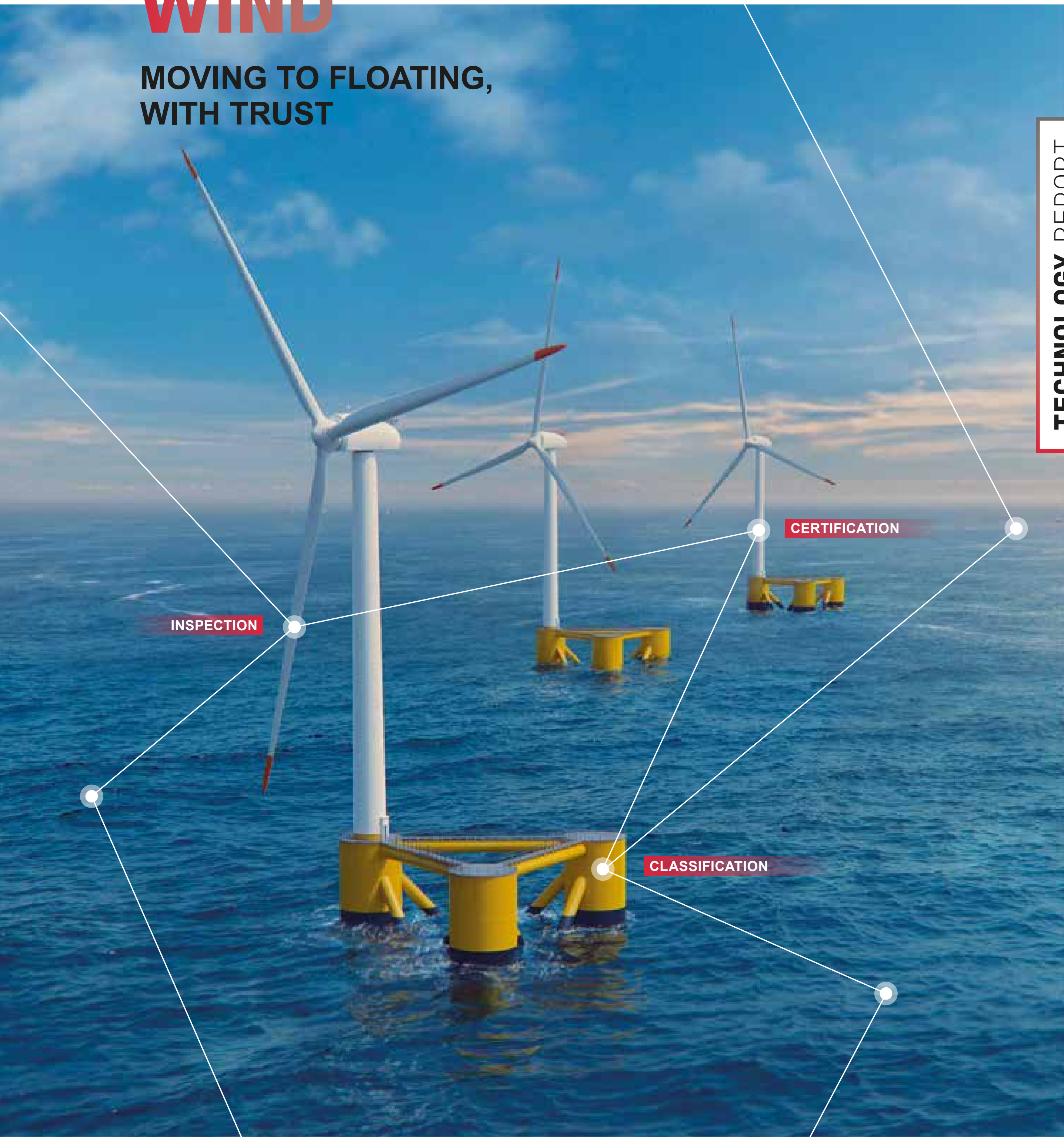
SEPTEMBER, 2021 #9

OFFSHORE WIND

MOVING TO FLOATING, WITH TRUST



TECHNOLOGY REPORT

BUREAU VERITAS

CONTENTS

ADDRESSING THE ENERGY TRANSITION: THE POTENTIAL OF FLOATING OFFSHORE WIND

DECARBONIZING ELECTRICITY

The objectives of the Paris Agreement are clear: to reduce the burning of fossil fuels in order to limit global temperature increase to well below 2°C, while pursuing the means to limit, in the longer term, the increase to 1.5°C.

The decarbonization of electricity production is set to play a significant role in this endeavor. To meet the Paris Agreement's objectives, forecasters consider that more than 16 terawatts (TW) of renewable energy capacity will need to be installed by 2050. Of these, 1.4 TW could be provided by offshore wind farms, according to the Ocean Renewable Energy Action Coalition (OREAC)[1]. This would mean 50 gigawatts (GW) per year of additional installed offshore wind capacity over the course of the next 30 years.

SCALING UP THE OFFSHORE WIND MARKET

Considering that there are approximately 35 GW of installed offshore wind capacity throughout the world today, with an annual growth rate of 6 GW per year, these are ambitious goals. Yet, as this Technology Report will show, the development of the offshore wind market is picking up speed. Bottom-fixed offshore wind technologies have matured significantly, and Floating Offshore Wind (FOW) is slowly but steadily developing to complement for deepwater zones.

In fact, the scale-up potential of FOW is significant. Currently they can be installed in waters up to 250 m deep, and as technologies mature, OREAC estimates that FOW farms could be installed in waters up to 1,000 m deep[2]. However, the road to technical maturity is complex.

REALIZING THE POTENTIAL OF FLOATING OFFSHORE WIND

While wind turbine technologies have now had time to mature, the floating foundations that provide the base for FOW turbines are still in the early stages of development. Coupling wind turbines' aerodynamic loads with floaters' hydrodynamic ocean loads also represents a complex challenge. To address this, it is not only necessary to apply lessons learned from the offshore wind and oil and gas (O&G) sectors, but also to work with partners who can provide a holistic view of an FOW project.

Bureau Veritas, both a leading Test, Inspection and Certification (TIC) society in the energy sector and a leading classification society for marine & offshore units, can provide such a view through several entities which may intervene at various steps of the FOW life cycle as detailed in this Technology Report. Having worked closely with industry players as a third-party independent verification body for both offshore wind and O&G, Bureau Veritas has significant experience in developing and applying technical standards and key safety regulations. This report is an opportunity to share the lessons we have learned through that experience. Further, this report will demonstrate how we can support society's energy goals by applying those lessons in order to collaborate with them on the FOW market of tomorrow.

> **"AS CAN BE EXPECTED WITH EMERGING TECHNOLOGIES, NEW CHALLENGES HAVE PRESENTED THEMSELVES, AND BV HAS BEEN BOTH RECEPTIVE TO AND FORTHCOMING WITH SOLUTIONS THAT ALLOW OUR DESIGNS TO PROGRESS TOWARD FRUITION."**
>
> Pablo Necochea, Lead Developer Floating Segment at Vestas

1. OREAC (2020), 'The Power of our Ocean.' Available at: https://gwec.net/wp-content/uploads/2020/12/OREAC-The-Power-of-Our-Ocean-Dec-2020-2.pdf
2.ibid

THE GROWING POTENTIAL OF THE OFFSHORE WIND MARKET

Over the past couple of decades, the offshore wind industry has made significant strides to become one of the most promising renewable energy sectors.

Yet, compared to onshore wind, its first steps have been relatively slow. In 2009, well into its first decade of existence, offshore wind still represented a mere 1% of global annual wind installations[3].
This was mostly a result of logistical challenges. As technology matured and CAPEX progressively decreased, however, offshore wind found its footing: by 2020, it had grown to represent 10% of global wind installations[4].

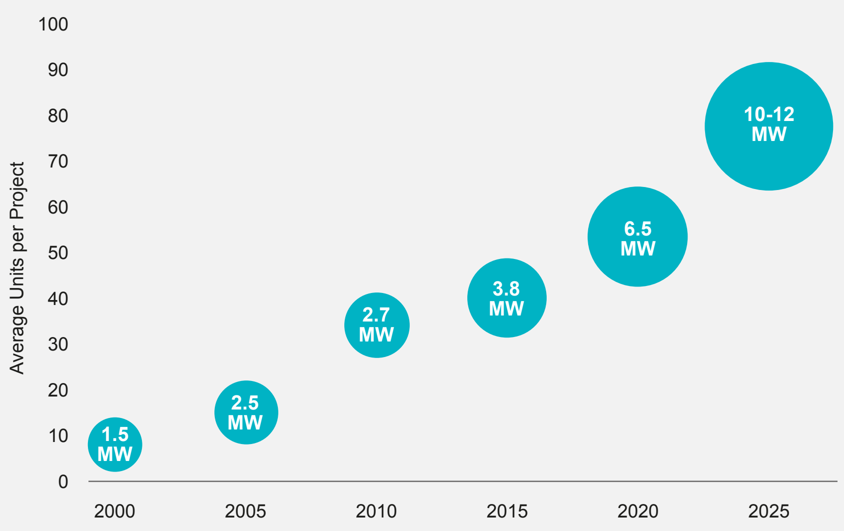
Market projections show that, as new regional markets emerge, offshore wind growth will continue apace.
It is also going to diversify.
While to date the majority of offshore wind installations are bottom-fixed, in the coming decades the industry will witness an increase in floating wind capacity. While still maturing, it has the potential to complement bottom-fixed technologies enabling feasibility and competitiveness towards deep water zones. FOW's promise is reflected in the increasing number of floating wind projects emerging worldwide.

10 YEARS OF GLOBAL OFFSHORE WIND GROWTH

Since 2013, the global offshore wind market has grown at an average of 24% per year. By 2020, this rapid growth had resulted in a global installation capacity of almost 35 GW. While this may appear limited compared to other renewable energies, this sector's exponential growth in a relatively short amount of time is remarkable and is forecasted to continue. It should also see expansion across the globe, with new regional markets opening up. Europe will remain the market leader for the foreseeable future in terms of installations numbers, however significant development is expected as well in USA and Asia.

This exponential growth is a result of the industry's significant potential. Looking at the average power rating of new wind turbines and projects in 2020, offshore wind produced 7.3 MW compared to 3.1 MW for onshore wind. This confirms the opportunity offshore wind presents to develop much bigger projects as compared to onshore wind.

EVOLUTION OF OFFSHORE WIND TURBINE AND PROJECT SIZE



** Expected average turbine size in markets outside China where average size is likely to be 7-8 MW.*
Source: GWEC Market Intelligence, June 2020.

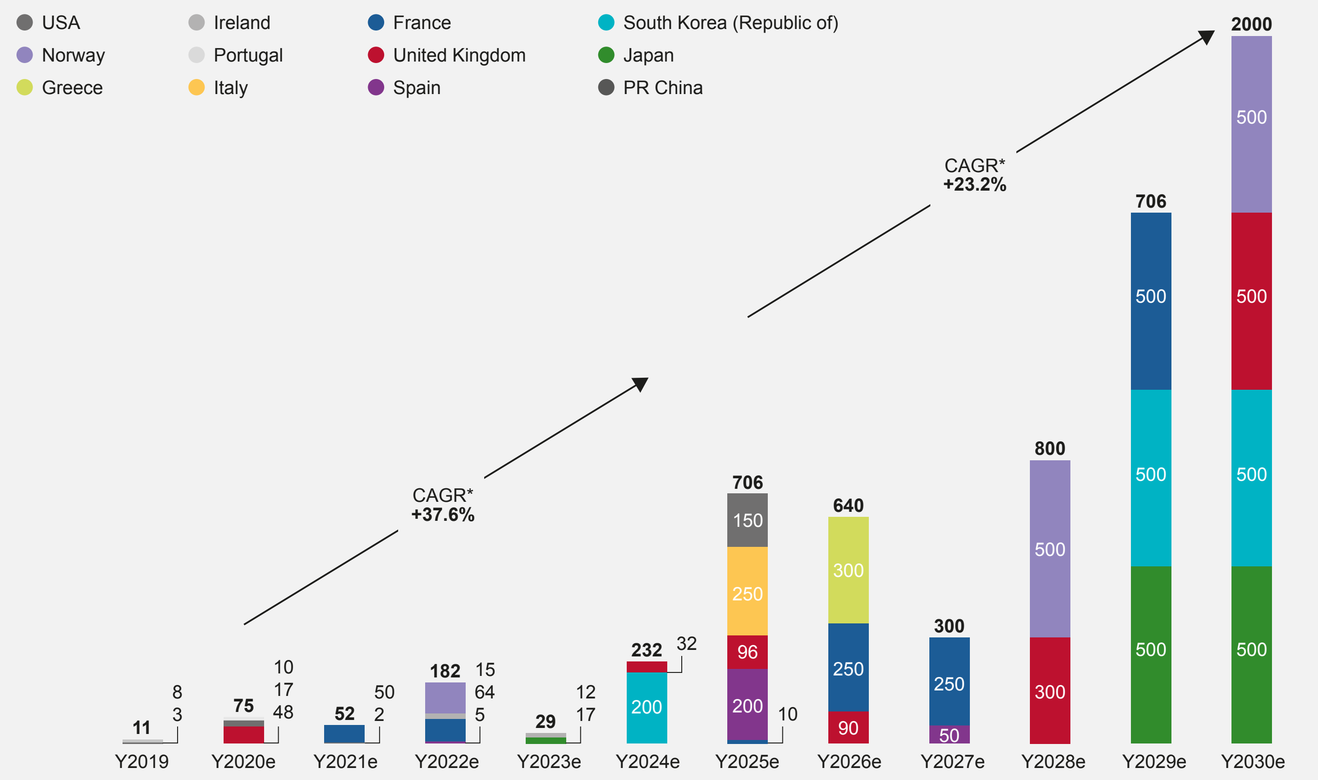
AN EMERGING FLOATING OFFSHORE WIND MARKET

Currently, however, the share of floating installations in the offshore wind market remains limited. In 2019, out of Europe's total offshore wind capacity of 22 GW, the largest regional capacity worldwide, floating wind still only represented 0.2% (45 MW) compared to bottom-fixed installations.

This is partly a result of floating wind technologies that are still maturing. Moreover, with existing projects only at the pre-commercial stage, the Levelized Cost of Energy (LCOE) currently remains high as compared to that of bottom-fixed, which has dropped by 70% since 2012[5].
A number of European floating projects are scheduled to come online between 2021 and 2025.

And with 6.5 GW's worth of FOW projects to be built by 2030, the floating wind market will grow at a rate of more than 25% per year. As such, the share of floating wind is likely to continue increasing, reaching up to +5% of annual installed offshore wind capacity by 2030.

NEW INSTALLATIONS (MW, FLOATING**)



** CAGR: Compound Annual Growth Rate*
*** Note: This floating wind outlook is already included in GWEC's global offshore wind forecast.*
Source: GWEC Market Intelligence, June 2020.

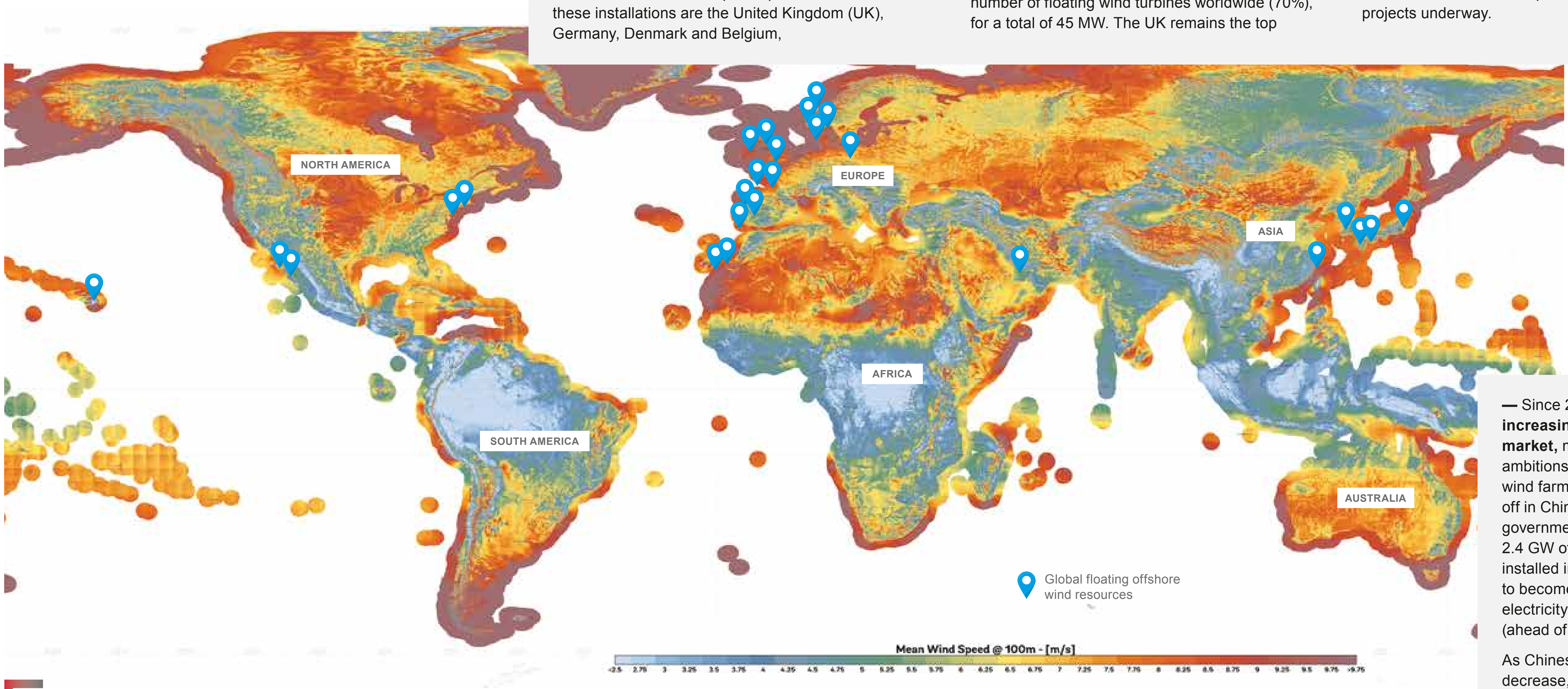
3. Global Wind Energy Council (2020), 'Global Offshore Wind Report 2020,' p.5
4. ibid

5. ibid

REGIONAL FLOATING OFFSHORE WIND MARKETS & TRENDS

— **Europe** has been leading the way since the early steps of the industry in the 1990s, and still **had the largest offshore wind market by installed capacity in 2020** with 75% of total offshore wind installations. The top European markets for these installations are the United Kingdom (UK), Germany, Denmark and Belgium, which together represented approximately 70% of total offshore wind installations in 2019.

Thus far, **Europe has also been leading the way in terms of FOW.** As of 2019, it had the largest number of floating wind turbines worldwide (70%), for a total of 45 MW. The UK remains the top European market, but auctions and tenders in 2020 reveal that France and Germany favor floating wind projects and are following closely. France in particular, despite a late start, now has four pre-commercial projects underway.



— For the **US market, offshore wind growth has been significantly slower,** mostly due to a complex regulatory scene involving the different laws of several East Coast states (e.g., Maine, Connecticut, Massachusetts, New York, New Jersey, Delaware, Maryland, Virginia and North Carolina). However, 2019 marked an important leap in the country's ambitions, with offshore wind procurement targets reaching 28.1 GW—a significant increase from 9.1 GW in 2018. The technical potential for offshore wind in the US is currently estimated at 2,000 GW.

The share of floating wind in the US offshore wind market, however, remains minimal. Significant potential has been identified on the West Coast of mainland US and around Hawaii, primarily as a result of water depths, and key international industry players are exploring a number of projects off the coast of California. Meanwhile, the East Coast state of Maine has established a $100 million partnership with Diamond Offshore Wind and RWE Renewables to build a full-size prototype.

— Since 2016, **Asia has represented an increasing share of the offshore wind market,** mainly as a result of Chinese ambitions. While Japan built its first offshore wind farm in 2003, offshore wind only took off in China in 2016, thanks to significant government subsidies. This resulted in 2.4 GW of offshore wind capacity being installed in 2019, and China expects to become the world's largest offshore wind electricity producer as soon as 2021 (ahead of the UK).

As Chinese subsidies for the industry decrease, other markets such as Taiwan, Vietnam, Japan and South Korea are likely to surpass China in terms of annual installations. **Japan and South Korea, in particular, are already launching a number of projects for FOW farms** with the contribution of an increasing number of international partners. In China, on the other hand, market projections expect only one floating wind demonstration project to be built.

Sources: Global Wind Atlas and QFWE

FLOATING OFFSHORE WIND: OPPORTUNITIES AND CHALLENGES

Although still in a relatively early, pre-commercial stage, FOW holds a number of opportunities for a wide variety of industry players. Yet, as with many emerging markets, a number of challenges remain. Certification and classification societies, such as Bureau Veritas, can play a significant role in supporting customers with addressing challenges to technological development.

Exploring Opportunities and Challenges

One of FOW's key advantages is the opportunity to install wind farms farther away from shore as compared to the bottom-fixed option. Bottom-fixed offshore wind can only be installed in shallow waters of less than 60 meters in depth. Beyond this limit, it becomes too financially risky to attach wind turbines to the seabed with traditional fixed platforms, effectively canceling any potential energy gains. For countries with long, shallow coastal areas, such as China or the UK, this has not been a challenge. However, other countries or regions, may present a bathymetry that reveals deep waters right along the coast, as is the case on the west coast of the US or the east coast of South Korea. For these areas, FOW is far more appropriate.

FOW also represents a greater potential in terms of wind speed. While certain areas of the world can experience high wind speed both along the coast and onshore (such as the UK), generally wind regimes are more stable, enabling a more steady power production, the further away from the coast one goes. FOW therefore opens up a number of areas further to shore where increased cost of distance to shore may be compensated by better wind resources.

Finally, FOW, much like bottom-fixed farms, could present significant benefits for both grid and off-grid application, as well as the potential reutilization of O&G platforms and pipelines. Off-grid could be used to power offshore assets, which is of particular interest to the O&G sector, but also for offshore conversion from power to gas (eg. Hydrogen) for long term energy storage, or other applications, once these technologies are mature enough.

However, beyond the technical challenges that will be explored in this report, a number of market challenges persist before floating wind can reach its full potential. To date, FOW turbines (including floaters) are still too costly as compared to bottom-fixed turbines (almost double the cost). Standardization and industrialization will play a significant role in driving down such costs, but this process is hindered by the multitude and variety of floater concepts currently at various stages of development (around 40 overall). Policy frameworks, which would be an incentive for the private sector to get more involved, are also missing. They are complex to set up because they need to account for the hybrid nature of floating wind farms, which combines the stakes of electrical equipment (gearbox, blades, electrical cables) and marine units (floater, mooring, dynamic cables).

WHAT DOES A FOW TURBINE INCLUDE?

FOW turbine refers to all the components of the floating system: Rotor Nacelle Assembly (RNA); Blades; Tower; Floater; and moorings.

Industry Partnerships

Cross-industry collaboration is essential to overcome these obstacles. Over the last few years, for instance, a number of O&G majors have gotten involved in the FOW market, generally working in partnership with utilities companies and/or technology developers. O&G sector experience and strategic capabilities are proving invaluable to the developers of FOW technologies, as well as those working on the regulatory framework.

This Technology Report describes the technological challenges and opportunities that floating wind assets represent throughout their lifecycle. It includes discussions about the support vessels (e.g. CTV, WTIV, OSV, etc) that transport technicians and install equipment.

DESIGN AND CONSTRUCTION OF FLOATING OFFSHORE WIND TECHNOLOGIES

Designing FOW technologies present a number of significant challenges. These technologies must be designed to withstand harsh marine environments and function in those conditions for a service life spanning over 25 years.

A number of turbine designs (e.g. rotor blade and tower) have already been tried and tested in the context of bottom-fixed offshore wind, but designing optimized floating substructures and mooring systems for FOW application can lead to engineering challenges. These emerging technologies need to meet the requirements of the complex loading environment created through the coupling of hydrodynamic and wind loads.

BV can leverage its expertise in the O&G and Wind Energy sectors, as well as the experience we are building on FOW turbine projects, to support customers in selecting and designing the right FOW turbine for a given site.

FOW DESIGNS AND CHALLENGES

There are currently four main types of floating wind foundations. Each presents benefits and challenges, as highlighted in the table below on the basis of the "Floating Wind Joint Industry Project Phase II Summary Report" findings[6].

The different floater design benefits and challenges presented in this table highlight three key design aspects to take into consideration when developing FOW technologies:

- **Site suitability** - Site condition assessment is generally the first step in the development of an FOW project. This assessment seeks to determine and characterize the most appropriate site on which to establish a wind farm. At the design stage, this analysis is critical to determining the type of rotor blade and tower to be used, based on prevailing weather and current conditions, and to selecting the appropriate mooring system.
- **Floater characteristics** - Evaluating the appropriate size and shape of the floater is critical to ensuring accurate buoyancy and stability under all prevailing weather conditions. The motion characteristics of the floater are also essential in order to select the most appropriate mooring system and determine the turbine's precise weight and height requirements.
- **Mooring** - The ability of the mooring system to withstand currents, but also to be strong enough to ensure station-keeping of the floater under all possible prevailing weather conditions onsite, including waves, swells and wind. Should the mooring system come undone, the FOW turbine would start drifting, risking collision with passing vessels and/or other FOW turbines on the wind farm.

MAIN FOW FOUNDATION TYPES

Foundation type	Benefits	Challenges
Semi-submersible	Features a relatively shallow draft, which makes it versatile, and is flexible for different site conditions.	Its high steel mass and many welded connections make it heavy and complex to manufacture.
Spar (Single Point Anchor Reservoir)	Well-proven, ballast-stabilized structure with a large draft providing high inertial resistance to pitch and roll motions.	The large draft can be a challenge for assembly sites, transportation routes and operational sites.
Tension-Leg Platform (TLP)	The tension-leg enables low structural weight of the sub-structure, reducing material costs. Combined with its shallow structural draft, it has limited motion during operation.	The risk of mooring failure presents high operational risks and adds constraints in relation to soil conditions onsite.
Barge	The shallowest draft of all, it facilitates installation of the turbine alongside a quay at a shallow draft location.	More affected by wave-induced motions, this design requires more robust mooring systems.

To date, there are approximately 40 different floater concepts at various stages of development, with Spain, USA and Japan leading in number of floater developed. All these concepts have to contend with the key design aspects highlighted above.
A large number of these projects have successfully completed model tests in a basin and are undergoing scaled prototype testing, but the investment required to move toward full-scale demonstrations has significantly held back progress. Moving forward, therefore, is largely dependent on the ability to de-risk these projects to attract more investment, and the market is likely to see a consolidation of the floater concept market under a few key players.
Industry partnerships, alongside the involvement of testing, inspection and certification (TIC) societies such as BV, can make an important difference in this context.

A Q&A with Seth Price, Vice President of Technology, Principle Power

What are the main challenges for Floating Wind Turbines?

One of the aspects that makes floating wind unique is the challenge associated with designing and deploying technologies that can adequately meet the requirements of the complex loading environment created through the coupling of hydrodynamic ocean loads and aerodynamic wind turbine loads. As turbines continue to grow in size and projects grow in scale, understanding these complex phenomena becomes increasingly important.

Developing efficient design solutions for utility scale applications can be equally challenging. As the industry moves toward 200 MW to 1 GW projects, industrialization challenges related to logistics and execution plans become increasingly dominant in the design process. It is necessary to understand the impacts of specific platform design decisions on fabrication methods, assembly and turbine integration methods, staging, and offshore operations in order to develop cost-competitive solutions.

As such, active cooperation on large commercial projects is required to accelerate industrialization of the technology and move our industry to the next phase. This work needs to actively involve technology companies like ourselves, energy companies, and the entire supply chain, including Certification Bodies, manufacturers and installation contractors.

One of the biggest industry challenges revolves around the development of a global supply chain that can deliver to customers at large scale and low costs. Global supply chain development will lead to building capabilities, local content and associated economic benefits (i.e., job creation and economies of scale).

How does your company address these challenges?

Over the last few years, and in response to our pioneering role in establishing FOW as a viable solution, we've had a shift in our focus away from simply demonstrating the technology to building an industry solution that can deliver commercial-scale projects at competitive prices using our WindFloat® technology.

**The WindFloat® is a three-column, semi-submersible, floating platform compatible with any standard offshore wind turbine and suitable for deployment in waters deeper than 40 m. With WindFloat®, wind farms can be optimally located, independent of depth and seabed conditions, enabling customers to access previously untapped sites with higher quality wind resources and minimum impact on stakeholders or the environment.
We've specifically developed the WindFloat® to achieve exceptional stability performance, while reducing structural weight and simplifying logistics during installation and operation.
The virtual pitch- and yaw-free performance in the offshore**

6. The Floating Wind Joint Industry Project (Floating Wind JIP) is a collaborative initiative between the Carbon Trust, Scottish Government, and twelve leading international offshore wind developers. The JIP aims to investigate the challenges and opportunities of developing large-scale commercial floating wind farms.

environment allows for the use of existing commercial offshore wind turbines, located at one of the columns, with only minor modifications to the control software.

As a technology company and an early mover in the industry, we have been uniquely able to help lead the development of the FOW sector in several markets. As such, the objective is now turning to industrialization for our product and our clients' execution plans – the focus is on delivering larger projects within timeframes and budgets similar to those of the FOW industry.

To meet some of the challenges associated with industrialization and leverage the global supply chain to its maximum extent, WindFloat®'s flexible and modular structural design enables a variety of local and global companies to participate in the manufacturing and fabrication, utilizing supply chains that strike the right balance between local content, cost and schedule. Additionally, our adjustable active and passive ballast systems enable wind turbine installation and large correctives to be performed at port with conventional land-based cranes. This removes the need for offshore heavy lifting, thus improving personnel safety and vastly reducing cost and weather risks. Lastly, to adhere to the strict schedule requirements of large-scale deployments, we've capitalized on our ability to design products to make use of simple offshore installation methods. The WindFloat® is inherently stable and can be towed to site by an offshore tug, where it is connected to the preinstalled mooring system in less than a day.

ADDRESSING KEY CHALLENGES

Resolving issues related to the design of technologies that are still maturing can be quite complex. Yet, with the right choice of industry partners, it need not be daunting.

A comparison between the floating platforms used for offshore O&G activities and the floater designs currently available for FOW shows that there are some key common characteristics (TLP, semi-submersible or spar). In practice, this means that some of the challenges identified for FOW technologies have already been tackled by the O&G sector, and leveraging that expertise is essential.

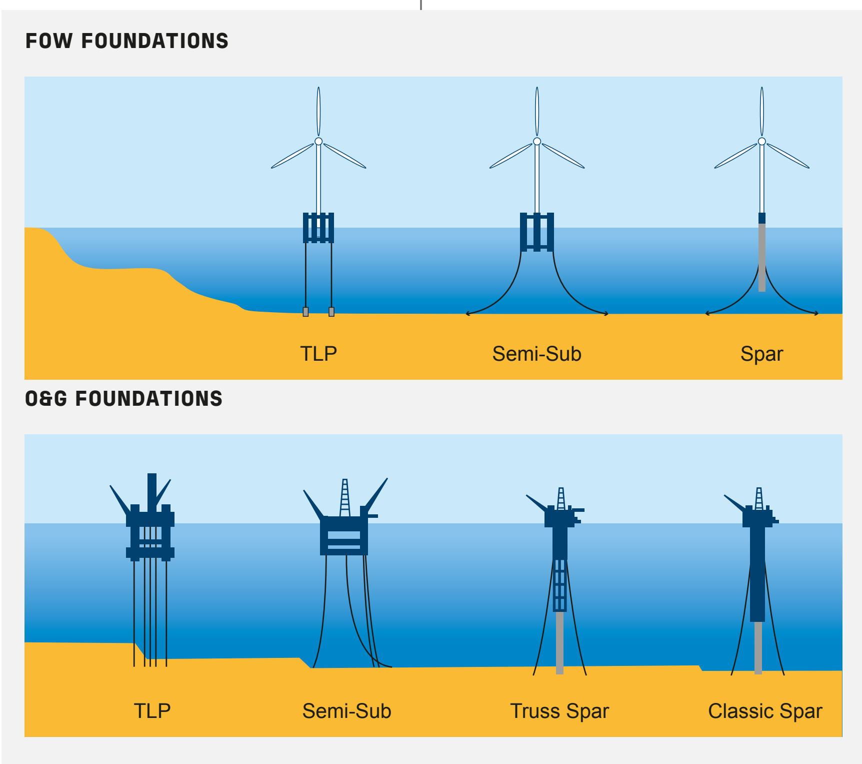
There are, of course, also significant differences between the two sectors, in particular the fact that FOW turbines are likely to be much more vulnerable to extreme weather events. In this sense, lessons learned from the bottom-fixed offshore wind market can also be applied to FOW.

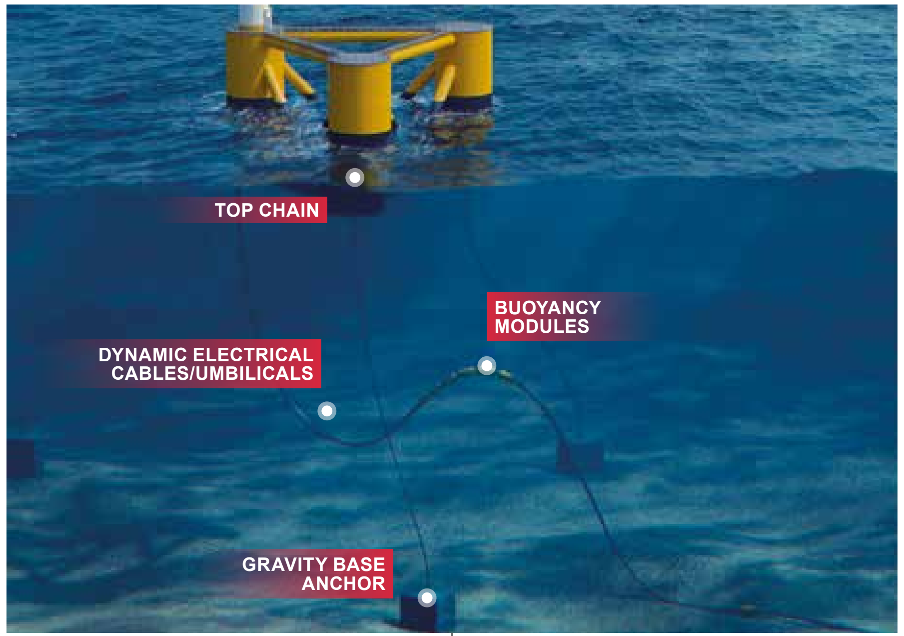
FOW market players are not stepping into a vacuum. While FOW technologies have their own challenges, bottom-fixed offshore wind and O&G sector best practices can be leveraged. They will be crucial to avoiding past mistakes and saving time and money for the development of more site-appropriate designs.

Seakeeping Analysis

The behavior of FOW turbines in waves needs to be evaluated at the design phase. This is relevant not only for FOW turbines in operation, but also for all transient phases (e.g., the transit phase of the FOW turbine from shore to wind farm site), as well as the installation phase (notably hook-up operations).

Based on an in-depth understanding of environmental conditions—during installation and while in operation—calculations need to be performed to help determine the motions of the FOW turbine. These computation aim to examine whether the site-specific loads and load effects on the wind turbine structure, including the rotor-nacelle assembly plus the support structure and supporting soils, are derived in accordance with industry practices, and in agreement with third party validated methodologies. These simulations will help ensure that the FOW turbine design can withstand any prevailing environmental conditions.





Mooring Analysis

To ensure maximum life expectancy, it is essential to understand how incoming currents, external local factors, extreme events and Vortex Induced Motions (VIM) can cause fatigue or stress on a mooring system.

Computations simulating these potential fatigue and stress factors are critical to support the development of an adequate mooring system for a given site. CFD simulations also contribute to determining the loads on the mooring and anchor equipment, the fatigue life expectancy of the system, and the floaters' maximum excursion value.

The latter is essential in designing FOW technologies for wind farms because it indicates the extent to which the floater can move around without colliding with another asset.

DE-RISKING TO MOVE FORWARD

FOW turbines' limited commercial deployment to date contributes to maintaining a certain level of perceived risk in a number of areas. And the need to continue investigating persists, even if many of the challenges encountered in this emerging sector can be addressed by using best practices taken from O&G and Wind Energy industries.

Only experience and careful analysis of potential risks can provide a strong basis for researching adequate solutions. De-risking also involves, in a less direct manner, working with all industry players to develop a strong and reliable supply chain.

BV Solutions M&O, a BV entity which aims to carry out engineering and technical expertise, may also support clients through a wide range of risk assessments that can contribute to de-risking projects. At the design stage, this can consist in the following:

- **HAZID[7] and HAZOP[8] workshops linked to the identification of risks.**
- **FMECA[9], to understand failure modes linked to the use of innovative technologies.**
- **Risk collision analysis, i.e., analyzing maritime traffic surrounding the wind farm site to understand the risk of collision with other assets, such as fishing vessels or other FOW turbines. This is done through an analysis of Automatic Identification System (AIS) traffic data and by using the data extracted during the mooring analysis.**
- **Fault-tree analysis, a top-down approach to identify the component level failures that cause the system level failure to occur. This facilitates quantification of risk related to events and / or combination of events, but also better address the requirement for redundancy and / or simplified systems**

Under the heading of 'owner engineering' services, BV Solutions M&O, may also support clients throughout the project's lifecycle. Owner engineering notably includes construction and industrialization supervision to de-risk the supply chain.

7. Hazard Identification.
8. Hazard and Operability.
9. Failure Mode Effects and Criticality Analysis.

TRANSPORT & INSTALLATION

Transportation and installation (T&I) of FOW turbines on a wind farm site is a complex and risky feat. Navigating the complexity of these operations necessitates an understanding of all the intricacies of the process.

It requires drawing procedures for the whole operation, from lifting FOW turbine components at assembly yard to the FOW turbine transportation (towing) and installation on site. It also requires that vessels selected for transportation - of crew and FOW turbines - and installation be safe, reliable and environmentally friendly.

Finally, it implies the need to select the right contractors so that all procedures are respected in compliance with marine warranty and to avoid any claims resulting from mistakes. In short, navigating the complexity of these operations requires a trusted partner with an overall view of the process.

DESIGNING T&I PROCEDURES

Transporting and installing FOW turbines involves moving different parts of an intricate system, from mooring and floating systems to wind tower and rotor blades, each with their own characteristics and constraints. The smallest mistake during one of these delicate operations can jeopardize the entire system; it can also be highly costly and time-consuming to fix. That is why it is crucial to develop procedures based on detailed analyses and calculations that will ensure the adequacy, reliability and safety of these operations.

Transportation Procedures

Transportation procedures are a key element in minimizing the risks associated with the transportation of all FOW turbine components. Risk begins when lifting the different components of the FOW turbine to assemble them at yard and continues when towing the FOW turbine to the windfarm site. It is critical to make sure that cranes and other systems used to move these parts at all stages of the process can withstand their potentially significant weight.

Once the FOW turbine has been assembled, it needs to be towed to site. This part requires careful calculations in order to ensure that the towing plan is defined in accordance with design and operational constraints, that the tow master and its crew are well trained and operating in safe conditions, and that the towed object will not suffer any damage during the towing operation between the sheltered fabrication assembly port and the final installation site.

All these challenges are assessed and mitigated through the transportation procedures, in order to ensure safety and protect crew and assets.

Installation Procedures

Experience in installing bottom-fixed wind and other offshore systems is only of limited support when it comes to FOW. The development of project-specific installation procedures can significantly reduce risks inherent to this delicate phase. These may include careful calculations of meteorological limitations to be imposed on heavy lift operations, and procedures for the installation of the mooring system.

INSTALLATION VESSELS

To date, because the FOW industry is still at the pre-commercial stage, existing vessels are being used to install FOW turbines. There are, however, a number of very specific challenges to the installation of FOW turbines that mean the status quo is only a temporary solution. Industry partners will have to work in close cooperation to retrofit existing vessels so as to address challenges for all stages of the installation process.

Anchor Handling Tug Supply Vessels

Anchor Handling Tug Supply (AHTS) vessels are used in the O&G and offshore wind industries to handle anchors, tow them to locations, and use them to secure rigs and offshore wind turbines in place. Though in high demand during the oil boom of the past decades, these vessels have seen their use largely reduced, due to the oil sector's recent crises.

The emergence of the FOW market is an opportunity for these vessels to find a new application, with some caveats:

- The repurposing of AHTS vessels for the green FOW industry means that project developers are more likely to select vessels that go beyond existing environmental regulations. To obtain these green credentials, AHTS vessel owners may choose to retrofit to a hybrid-diesel electric propulsion system. Beyond the obvious advantage of the greener propulsion, hybrid-diesel electric propulsion systems' batteries can be used to increase the level of redundancy during Dynamic Positioning (DP) operations.

AS A CLASSIFICATION SOCIETY, BV HAS EXPERIENCE IN THREE DOMAINS CONCERNING T&I VESSELS' CLASSIFICATION

- In 2017, BV released its new rules for offshore service vessels and tugs, Rule NR467 part E, which include specific guidance for bollard pull measurements.
- In 2020, BV released its new notation for Ultra-Low Emission Vessels. Going well beyond current MARPOL requirements, this new notation is critical to ensuring vessels exceed environmental regulations.
- BV is classing the new offshore installation vessel Voltaire, a ship designed by Jan de Nul company and capable of transporting, lifting and installing next-generation offshore wind turbines. Delivery of this vessel is scheduled for 2022, and if it meets the relevant standards, it will receive BV's ULEV notation.

This prevents the use of two generator sets at the same time and contributes to a more environmentally efficient vessel.

- Anchor handling operations are critical from a safety point of view and the bollard pull (their towing capacity) is the main value used to assess stability during these operations. As such, it needs to be carefully measured to avoid any potentially life-threatening accidents during anchor handling operations.
- Dynamic Positioning (DP) systems are critical when securing FOW turbines in place. They ensure that the vessel remains in position so that surge, sway and yaw are controlled and do not endanger the whole operation.

Cable Laying Vessels

FOW turbines are connected to two types of cables:

- Inter-array cables, connecting wind farm units to each other and, where relevant, to the substation that collects and channels the energy produced by the turbines
- Export cables, connecting the substation to the station on land or, if there is no substation, exporting power directly to the station onshore.

Installing these cables is a particularly complex and high-risk operation. Similar to AHTS vessels, these vessels must be able to maintain their position at all times, being fitted with excellent DP systems, and conform to the highest environmental standards.

Led by accredited experts, BV Solutions M&O provides cost-effective ways to enhance safety and operability according to specific vessel applications. Our multidisciplinary technical and operational experts were among the first DP vessel analysts ever to attain International Maritime Contractors Association (IMCA) accreditation. Having achieved this high standard, they leverage their wealth of experience to ensure an asset's compliance and optimal efficiency.

MARINE WARRANTY SURVEYOR

Developing T&I procedures and selecting the right vessels and contractors is critical to ensuring the safety of operations. It is also indispensable for insurance purposes.

The T&I phase of the FOW systems lifecycle is arguably the most delicate one, and project developers are required to secure construction all-risks (CAR) insurance policies to cover the scope of these activities. Within the CAR policy, a 'warranty clause' requires the project developer to retain the services of a Marine Warranty Surveyor (MWS). MatthewsDaniel, a BV company and a global leader in pre and post risk services, risk assessment and loss adjusting, can support the design of T&I procedures as per the industry requirements.

Moreover, MatthewsDaniel's experts apply lessons learned from their loss adjusting experience working on projects in which they were not acting as the MWS provider. With this invaluable access to critical data related to risks and failures affecting offshore wind projects, MatthewsDaniel can break the repetitive cycle in which the industry seems to be stuck.

WHAT IS AN MWS?

The role of the MWS is to:

- Review T&I operations procedures
- Carry out suitability inspections for vessels and equipment
- Oversee operations to ensure that procedures are respected and issue certificates of approval

This will prove particularly relevant as FOW farms move into deeper waters, resulting in more complex cable lay installation activities. (The T&I aspect of a project is subject to the highest level of claims for offshore assets.) As wind farms become bigger, it will also involve an increasing number of wet tows of assets to sites, which increases the chance of risk.

At MatthewsDaniel, experts are qualified under the Society of Offshore Marine Warranty Surveyors (SOMWS) and have extensive experience as MWS for floating structures. Through this combination of experience and expertise, they support clients across every phase of the transportation and installation of FOW systems.

In addition, MatthewsDaniel's dedicated geotechnical group has expertise in foundation studies, on-bottom stability, Site Specific Assessments (SSAs), and sediment transport studies for near and offshore projects. Their expertise extends further than this to modeling complex offshore tows. MatthewsDaniel does this by utilizing SafeTrans—a joint industry project in which the company is a founding member—and weather services such as forecasting and historical hindcasting of meteorological events.

A Q&A with Pablo Necochea, Lead Developer Floating Segment at Vestas

What are the main challenges for Floating Wind Turbines?

The obvious challenge is that the turbine is not fixed to the seabed by an embedded foundation. Due to this, we have to take considerably more into account than we would for a fixed wind turbine. A floating turbine presents challenges with stability, not only in the operation phase, but also during installation. Each wavelet in the port heaves the floating foundation, requiring a grounded floater and perfect orchestration among the lifting teams.

There is also a diverse range of floating foundation designs, meaning that for each project Vestas must find the right interface between turbine and floater. This involves significant effort and collaboration between the OEM, the foundation designer, and the project developer. Jointly, the three parties must model and design the sensible balance between foundation cost and energy production.

Floating wind today has a higher cost of energy than a bottom-fixed project, due to these projects' smaller size and inability to benefit from economies of scale. As FOW goes commercial, foundations will be optimized in size and manufactured using industrialized methods at a much larger scale, leading to a sharp decrease in cost. CAPEX will also decrease sharply as lenders get comfortable with the risk profile of floating wind. We should see further decreases in cost thanks to the opportunity for quayside installation, because FOW does not require costly installation vessels.

How does your company address these challenges?

Since we're still in the early stages of expanding the floating wind industry, new solutions are required for new problems. We must, therefore, work closely with all our partners, such as foundation designers and project developers. In this way, we can ensure that the interface between floater and turbine has been optimized in terms of loads, WTG performance and floater cost. We also want to be sure that everyone is on the same page prior to manufacturing. This requires a lot of intense upfront modeling. Our coupled modeling software takes the complex mooring lines and foundation models to simulate thousands of hydrodynamic and aerodynamic load cases, the results of which are used to optimize the foundation and turbine design, and ensure a sensible WTG performance.

We work closely with installers to make sure that turbines are safely installed on calm waters, and then towed out to the project site. Lastly, we collaborate with foundation designers, lending our expertise on mass production, which is the segment of the floating wind supply chain that should see the most significant cost reductions.

OPERATIONS

Only a very limited number of FOW farms are currently in operation, so experience with FOW turbines in operation is limited. However, the similarities that exist between these assets and O&G floating platforms, as well as fixed offshore wind assets, should prove helpful.

Operators and TIC companies could use these similarities as an entry point to explore how to ensure that FOW farms run as smoothly as possible. This involves identifying techniques and lessons learned from O&G and Wind assets operation and applying them to FOW. It can also include looking into vessels currently being used to transfer crew and carry out maintenance operations.

ASSET OPERATION: ANTICIPATING EFFICIENCY & EFFECTIVENESS

Power grids around the world are likely to become increasingly reliant on FOW as associated designs and technologies are de-risked and LCOE decreases. The aim of asset operation is to ensure safety, integrity and performance of FOW turbines throughout their lifecycle.

FOW Turbines in Operation

Remote Inspection Techniques (RIT) could bring a number of benefits to FOW clients. These techniques, which include the use of technologies such as drones and underwater vehicles, have the potential to considerably facilitate the task of experts onsite. Some benefits include:

- They are safer. The use of drones and underwater vehicles reduces the need for expert inspectors to go onto the platform or dive under it.
- They save time. No longer required to go 'onboard' for every inspection, experts can carry out their tasks faster and with less preparation time than would otherwise be required to ensure onboard safety.
- They produce higher-quality records. The data derived from RIT technologies ensures better inspection history tracking. Data may also be used to feed Artificial Intelligence (AI) developments and 3D models.

Over the past couple of years, BV has been working extensively on RIT with a number of clients on various platforms.

BV Solutions M&O has been working with O&G clients for years to support them with efficient asset operations in three ways:

- **Regular inspections comprising regulatory controls, remote and onsite inspection techniques, including advanced blade inspection**
- **Testing, monitoring and analysis, such as Structural Health Monitoring (SHM), lubrication management, vibration analysis and performance monitoring and verification**
- **Engineering and technical assistance, including principal components analysis, and maintenance and inspection**

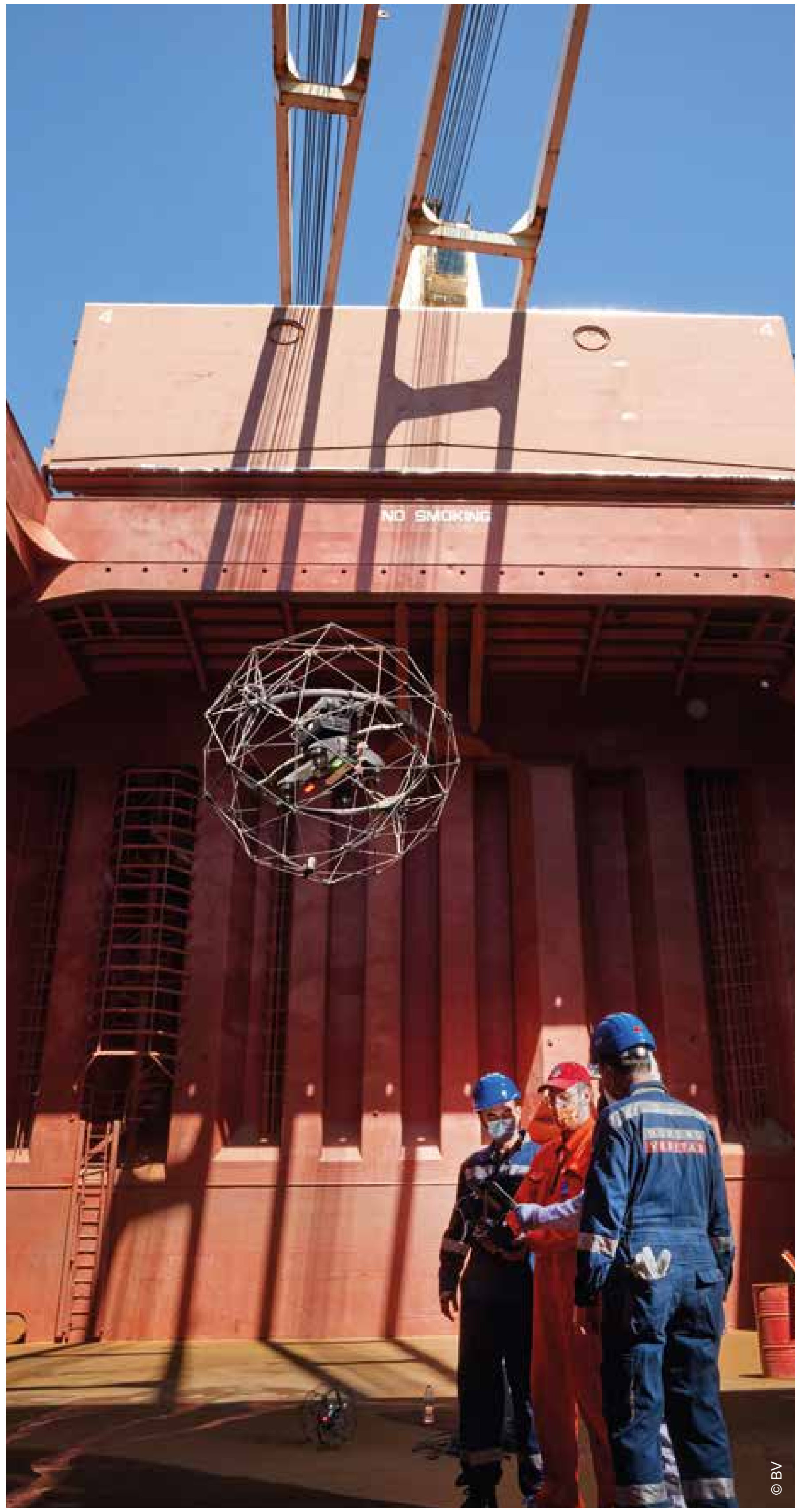
Cable Operation

Today, cables—both inter-array and export—represent approximately 15%-25% of the total cost of an offshore wind farm. However, cables represent approximately 80% of claims value for offshore wind, the root cause of which is mainly mechanical. This is clearly evidenced by loss adjustment data gathered by MatthewsDaniel concerning major claims caused by:

- Fiber optic failures due to manufacturing defects (electrical)
- Faulty repair joints (electrical)
- Inter-array and export cable damage during pull in (mechanical)
- Damage during installation due to human error, weather effects, machinery breakdown, etc. (mechanical)
- Damage by fishing trawlers, anchor dragging, jack-up construction vessels, etc. (mechanical)

Cables are a critical piece of the wider FOW infrastructure. Without them, the energy produced by FOW turbines does not reach the sub- and main stations, failing to feed the national grid to which they are connected. To address these issues, cable installation and operation can be included in the project certification process of FOW farms. Today this is only optional, with the certification process focusing on the wind turbine, substation and foundation.

To address a number of issues related to cable claims, BV has partnered with leading international cable manufacturer Nexans. This new partnership aims to establish minimum standards for cable manufacturing and installation to limit cable claims. It will raise awareness of the importance of carefully selecting cable manufacturers and cable laying operators to reduce risks and ensure full operational functioning from the start.



BV has been pioneering a variety of RIT for offshore and marine assets.

MAINTENANCE & OPERATIONS VESSELS

Cable layers and FOW turbine transport vessels are necessary not only during T&I, but also in a repair role when issues arise with cables or turbine parts. Service Operation Vessels (SOV), currently being used in the fixed offshore wind sector, might also find new uses in the context of FOW farm operations.

SOVs are crucial for the operational maintenance of O&G platforms and fixed offshore wind turbines. While they remain necessary for maintenance, issues have arisen over the act of transferring technicians and equipment from a floating vessel to a floating platform.

For the transfer of technicians to fixed offshore wind turbines, SOVs have a high level of redundant components, such as the motion-compensated gangways that work in combination with DP systems. In the context of FOW, however, these two systems would have to be very accurately integrated with one another and ship motions to avoid adjustment. Walk-to-work accessibility is under assessment for FOW, and would provide an increased safety for all manned O&M operations.

BV Solutions M&O can support clients in successfully carrying out the integration of these two systems with ship motions.

CERTIFICATION

UNDERSTANDING FOW CERTIFICATION

What is Certification?

Certification is the process of assessing the conformity of a product, system or service with the requirements and characteristics outlined in a standard, specification or regulation. These standards or specifications are published by recognized international bodies and serve to provide proof that a product, system or service is safe and performs as promised.

Why undergo Certification?

Certification is not a mandatory administrative requirement for products, systems or services, although for certain systems, such as marine units, national authorities may make it compulsory. Rather, certification is usually requested by insurance companies in order to lower the level of risk and, subsequently, decrease the insurance premium. It is also requested by lenders to provide the needed confidence in the financing process.

On a more general level, certification is a common practice within certain industries to guarantee consistency of design and manufacturing across all subcontractors, as well as to ensure that best practices have been properly implemented.

Applying Certification to FOW

Certification for all offshore wind components can be applied in three different scopes. These are clearly defined in Bureau Veritas Guidance Note NI631 (Certification Scheme for Marine Renewable Energy Technologies), in line with International Electrotechnical Commission (IEC) certification structures, and are as follows:

- Component certification: applies to designers and manufacturers of components such as blades, gearboxes, towers, etc.
- Type certification: applies to wind turbine designers and manufacturers
- Project certification: applies to wind farm developers, and seeks to ensure that the FOW turbine design, and the consequent specific supplied units are manufactured, transported, installed and operated in compliance with certain requirements and are suitable for the specific site conditions.

Applying these different types of certification to FOW, however, comes with a number of challenges.
This is mostly due to the fact that FOW turbines are particularly complex. Not only do they feature a large number of components with varying degrees of technological maturity, but they also involve a wide variety of stakeholders, from design and construction all the way to installation and operation.

Component and type certification, for instance, are currently only applicable to the wind turbine and associated energy production systems. Conformity assessments can be carried out on the basis of international standards for wind energy generation systems established by the IEC. The technical standards within the IEC 61400 series, developed and maintained by the Technical Comitee 88 at IEC, apply to wind turbines, wind power plants (onshore and offshore), and the interaction with the electrical systems to which energy is supplied. The IEC system for certification to standards relating to equipment for use in renewable energy applications (IEC RE) is responsible for developing the scheme to ensure conformity with IEC technical standards.

Type certification is not applicable to the floater supporting the wind turbine as IEC standards do not exist for such FOW elements. Instead classification societies propose Approval in Principle or Basic Design Approval of the floater specifically designed and optimized for each project.

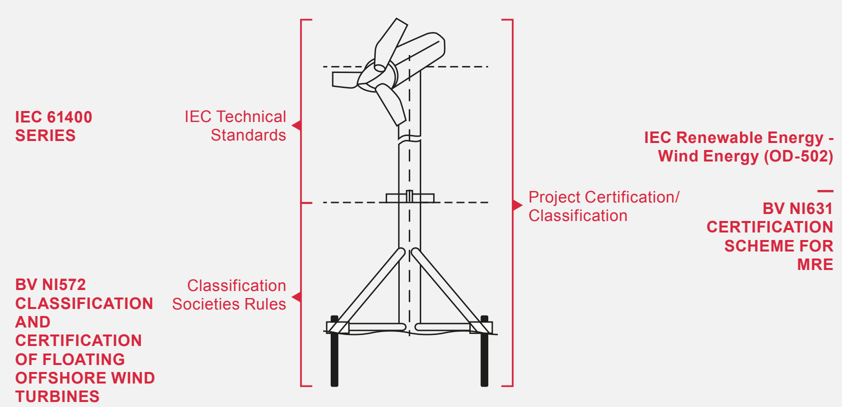
FOW Project Certification

Project certification can be divided into two main phases:

- Design, including verification of the project developer's site conditions assessment, reviewing the basis of the project design to ensure appropriate applicable standards and norms and sound methodologies, and examining the site-specific loads, as well as the entire wind turbine design for conformity with the design basis
- Construction, installation and commissioning, to ensure that these operations are carried out in full respect of manuals, procedures and established safety standards

Optionally, project characteristics, such as power curves, can be certified. Certification of the Operation and Maintenance module can be maintained during the in-service phase.

APPLICABLE TECHNICAL STANDARDS AND CERTIFICATION SCHEMES



WHAT IS THE IEC?

The IEC is a global, not-for-profit membership organization, whose work underpins quality infrastructure and international trade in electrical and electronic goods. To date, the IEC has published around 10,000 IEC International Standards that ***serve as the basis for risk and quality management and are used in testing and certification to verify that manufacturers keep their promises.***

WHAT IS TC 88?

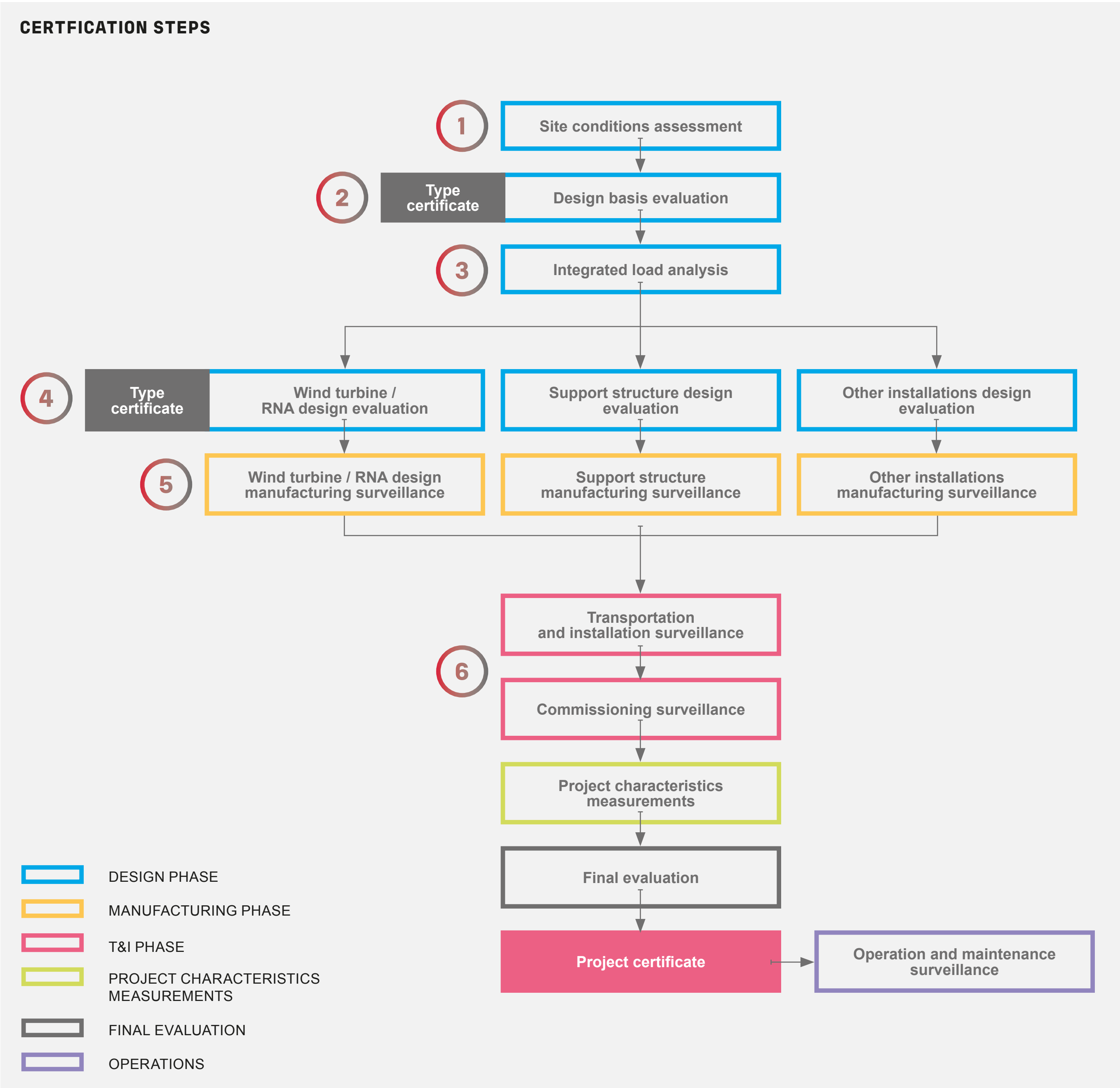
TC 88 is standardization in the field of wind energy generation systems, including wind turbines, wind power plants (onshore and offshore), and interactions with the electrical system(s) to which energy is supplied. BV is a member of the IEC TC 88 working group, which produces standards that address site suitability and resource assessment, design requirements, engineering integrity, modeling requirements, measurement techniques, test procedures, operation and maintenance. ***Its purpose is to provide designers and project developers with a basis for design, quality assurance and technical aspects.***

WHAT IS THE IEC RE?

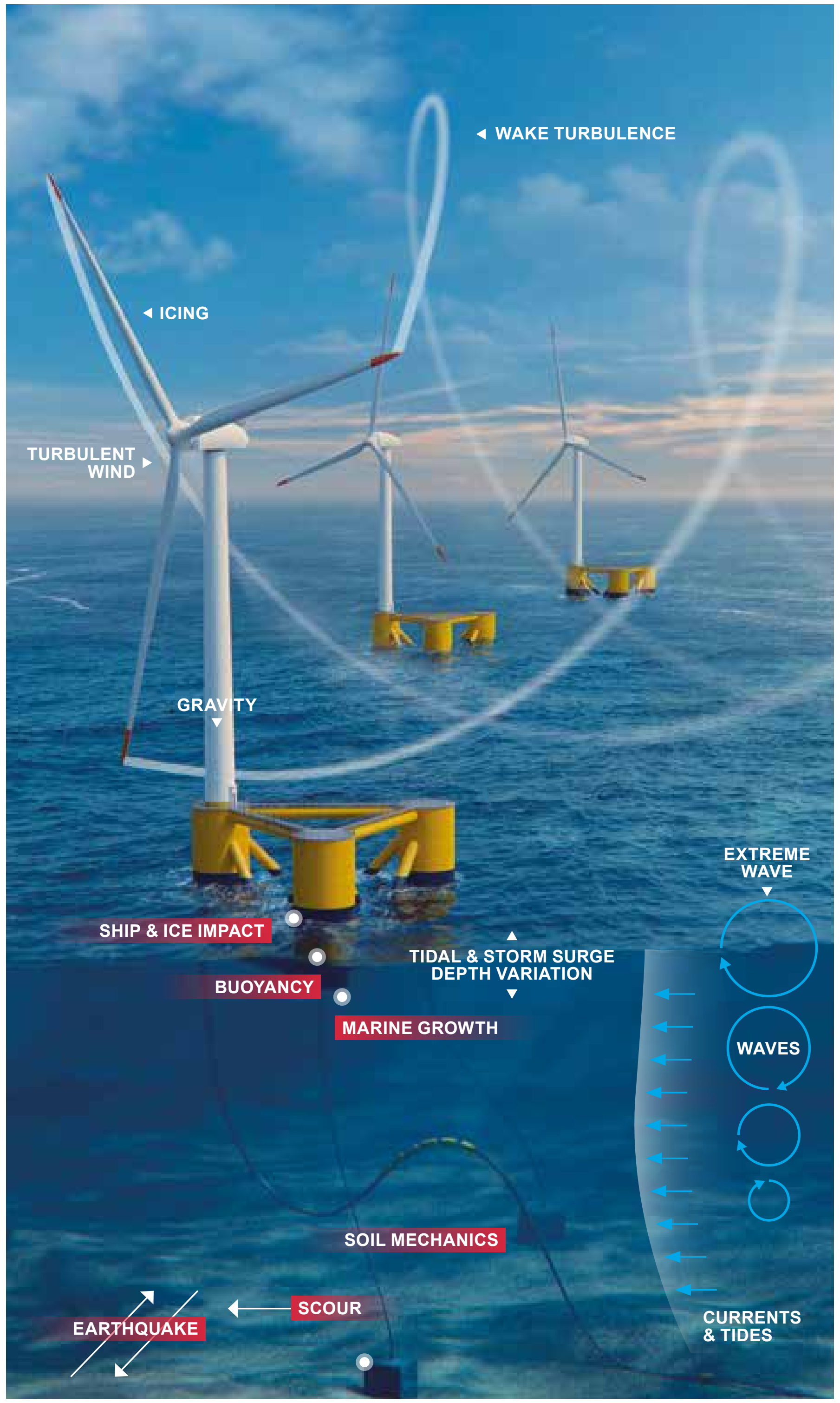
The IEC RE is composed of three sectors (wind MRE - Marine Renewable Energy - and solar) among which dedicated working groups are developing Operational Documents (OD) that provide overall governance for the IEC RE system.
These ODs notably specify the means to carry out certification schemes, and the requirements associated to each scheme and associated module. **The OD 502, in particular, specifies procedures for the wind certification scheme.**

PROJECT CERTIFICATION

The following sections provide an overview of the challenges related to the certification of FOW projects in each phase, and how BV can support customers each step of the way.



1. SITE CONDITION ASSESSMENT



The site condition assessment seeks to answer the question: **has the assessment been adequately undertaken and documented?** A proper assessment of site conditions should include two key elements: a Metocean report and an analysis of soil conditions.

The **Metocean** report is necessary to ensure that floating wind turbines will be able to withstand all the different meteorological conditions above and below water that are likely to affect them throughout their lifecycle. A floating wind turbine that is vulnerable to meteorological elements such as currents, tides, waves, wind, marine growth and scour is not safe. Similarly, if turbulence, wind shear, or the vertical speed profile of the wind are not adequately assessed, the wind turbine's structure and its power performance are unlikely to yield good energy results.

Although floating wind turbines are moored and anchored to the seabed, rather than fixed, **soil conditions** do need to be accurately analyzed. It is crucial to ensure that bathymetry, the nature of the soil, composition of layers, and scour have all been checked to avoid interference with the anchoring system. A detached floating wind turbine is dangerous both for the environment and for the structural integrity of the whole wind farm.

It is the certification body's role to review the specifications and procedures used for the site condition assessment to certify this stage of the project.

2. DESIGN BASIS

This module of the project certification scheme seeks to answer the question: is the basis for designing the floating wind system sufficient to safely design and execute the project?

This first step of the design review for project certification aims to ensure that the floating offshore system's original design complies with:

- Grid compatibility
- Site-related constraints
- Certification standards for each component

Agreed, the doc review (of the Design Basis) include the review of all the technical standards applied for designing the different FOWT components, notably to ensure coherence at interfaces.

The certification body reviews all documents provided by different project stakeholders (i.e., project developers, turbine and tower manufacturers, floater structure manufacturers, mooring systems manufacturers) to ensure that the design basis for the whole system reflects the standards applied to each component.

As noted earlier, there are currently no international standards that address all aspects of floater system certification. Thus, the support of a classification society like BV is crucial to ensure the system is safe and consistent with the whole design. In fact, BV has already developed a set of rules for the classification and certification of FOW turbines (BV NI 572)—including floater structure—which can be applied here.

"IT'S BEEN A PLEASURE WORKING WITH THE EXPERTS AT BV. THEIR ENGINEERS ARE ALWAYS OPEN TO DISCUSSING RULE INTERPRETATIONS AND PROBLEM SOLVING FOR ANY OF THE CHALLENGES THAT MAY PRESENT THEMSELVES THROUGH A PROJECT'S DESIGN PHASES. WHERE RULES ARE MORE BASED ON EMPIRICAL EVIDENCE AND HISTORICAL NORMS, SUCH AS CORROSION PROTECTION, IT'S IMPORTANT TO DISCUSS THE VARIABLES SPECIFIC TO THE GIVEN PROJECT SITE AND STRUCTURAL DESIGN TO FIND THE OPTIMAL SOLUTION. BV BRINGS A WEALTH OF KNOWLEDGE AND WELCOMING CULTURE, WHICH IS SOMETHING THAT PRINCIPLE POWER VALUES HIGHLY."

Seth Price, Vice President of Technology, Principle Power

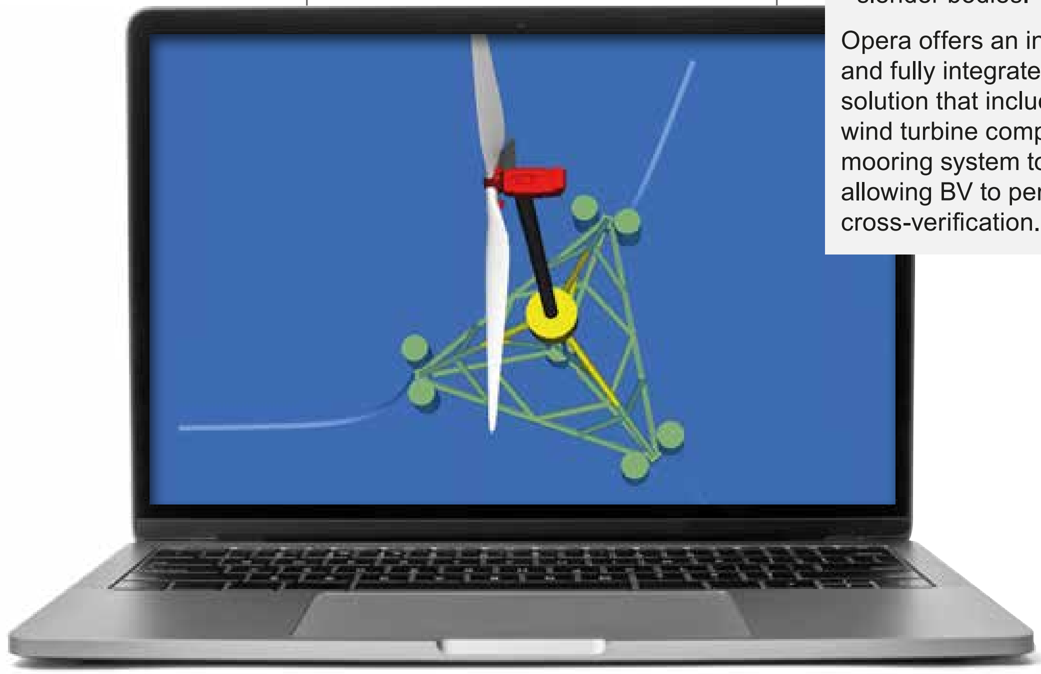
3. INTEGRATED LOAD ANALYSIS

The Integrated Load Analysis (ILA) addresses the question: are the site-specific loads derived in conformity with the design basis? This project certification phase perhaps best exemplifies the certification body's vital role in verifying the cohesion of such a complex project, where many stakeholders and components are involved.

To demonstrate the project's complexity, we can look at the separate assessments and design checks required by different entities. On the one hand, the turbine and Rotor Nacelle Assembly (RNA) sub-systems are studied to check onsite wind conditions range, floater motion and acceleration envelopes.

On the other hand, the floater structure has been pre-dimensioned separately to take into account wave and current loads, mooring loads, and turbine thrust, as well as modal excitations of turbine rotation.

The certification body is therefore crucial for two reasons. First, the different entities most likely will not be using the same software for their calculations. The certification body can check that both entities' results match when coupled in one site-specific design. Second, each entity is focused on its field of expertise and relies on the other to address the issues on which they have less expertise. Because a certification body has access to both sets of information, it can ensure full cohesion between the two sides and validate the ILA for the project.



OPERA: A NEW SIMULATION TOOL

In 2021, BV released OPERA, a new sea-keeping and station-keeping simulation tool for the certification of floating units, notably floating wind turbines. OPERA gathers all BV knowledge to model any type of multi-physics systems including:

- hydrodynamic, aerodynamic and mooring loadings,
- mechanical couplings,
- wind turbines controllers,
- rigid bodies and deformable slender bodies.

Opera offers an independent and fully integrated modeling solution that includes all floating wind turbine components, from mooring system to blades allowing BV to perform full cross-verification.

4. DESIGN EVALUATION

This stage of the certification process seeks to answer the following two questions:

- **Is the wind turbine designed and documented in conformity with the design basis?**
- **Is the design adapted to the observed, site-specific conditions?**

In this final design phase of the project certification process, the certification body ensures that the final design is aligned with the design basis. This step is relatively simple for the wind turbine, as site-specific loads are verified for conformity with the ranges of allowable loads specified by the RNA certificate. In relation to the floater and the tower, this process is more complex.

BV has developed a methodology designed to facilitate this step and ensure safety and alignment. In addition to reviewing all documents provided by different stakeholders, BV carries out independent structural analyses (strength and fatigue) to verify the results presented by tower and floater designers, based on the loads assessed during the ILA module.

5. MANUFACTURING, INSTALLATION AND COMMISSIONING

During the manufacturing phase, the role of the certification body is to address the following questions:

- Is the quality system of the manufacturer ISO 9001 or certified against an equivalent standard?
- Are these operations compliant with their respective manuals, procedures and safety standards?
- Is there any excessive loading on the structure?

In order to answer these questions, BV carries out a documentation review to ensure that the components manufacturing process is in line with the specifications included in the Engineering, Procurement and Construction (EPC) contract. This phase also includes BV inspections and audits to certify that all components and processes are compliant with manuals, procedures and safety standards.

The transportation, installation and commissioning phase is critical. The floating wind system and components can be severely damaged by the smallest mistake in assessing the load on the transporting vessel, towing, or weather in which the installation will take place.

BV combines its experience on O&G floating units and fixed offshore wind projects to perform T&I certification. This consists of reviewing the T&I procedures outlined during the early phases of the project and making sure they are being followed during the T&I project phase.

BV ENSURES SYNERGIES

As both the certification body and MWS act in parallel during the T&I phases, BV has developed synergies compliant with potential conflict of interest management between these 3rd party services to avoid redundancies and optimize the overall scope of work.

BV RULES FOR MOORING

The following BV rules can be applied for the certification of the transportation and installation of mooring system components, as well as the hook-up and pre-tensioning of mooring lines:

- NR493 for the classification of mooring systems for permanent and mobile offshore units
- NR432 for the certification of fiber ropes for deepwater offshore services.

THE POTENTIAL OF CLASSIFICATION IN THE FLOATING OFFSHORE WIND MARKET

Today, certification is the main approach being used to assess the conformity of FOW components and projects. It is a well-known process adopted by most traditional wind actors.

However, as this Technology Report has demonstrated, FOW technologies are not traditional. While wind turbines are well-developed technologies to which IEC standards apply, the floaters and moorings being used for FOW turbines are emerging technologies with significant maritime specificities. Classification Societies already have standards and rules in place for floating technologies that may be a relevant alternative to assess and ensure the conformity of FOW floater and moorings.

Floaters and moorings are marine components installed in national waters. Classification societies, such as Bureau Veritas, have a long experience in certifying such units for the offshore O&G sector. They have been working closely with flags to adapt programs to their requirements **and they have experience in developing standards.** Because of this, they already have standards and rules in place that can be used to assess conformity of floaters and moorings to ensure FOW turbines' safety.

A Q&A with Pablo Necochea, Lead Developer Floating Segment at Vestas

What do clients expect from a certification company or classification society?

The ability to engage in a greater number of projects and industries provides the certifying bodies with great potential for capturing synergies and developing improvement ideas that could be applicable across the industry. Since classification societies and certification bodies work across many industries, we expect their expertise and know-how to be key contributions for the FOW segment, which in practice represents a marriage of the O&G and offshore wind industries.

Bureau Veritas has published NI572 on classification and certification of floating offshore wind turbines. It provides specific guidance and recommendations for the classification and certification of floating platforms designed to support FOW turbines and is intended to cover floating platforms supporting single or multiple turbines with horizontal or vertical axis.

Bureau Veritas has also published NI604 rules on fatigue of top chain of mooring lines due to in-plane and out-of-plane bending.

The experience and expertise acquired by classification societies in the marine and O&G sectors can significantly contribute to supporting FOW technology innovation. This is particularly true for floaters, for which classification societies can offer Approvals In Principle (AIP) to review and approve innovative designs not covered by existing rules. Based on this, classification societies can subsequently publish new technical standards to ensure that the level of safety for new technologies is in line with marine industry best practices.

Last but not least, while classification and certification schemes are very similar – they both cover the phases described in the previous section – there are a few differences that could make classification particularly interesting for FOW projects. Firstly, classification societies have a long and proven experience in monitoring floating assets throughout the in-service phase, including procedures to transfer assets from a classification society to another as well as asset-centric information systems to record regulatory and condition data. They also have in-depth relationships with local maritime authorities enabling them to manage any type of maritime event or incident.

Secondly, while a number of different certification bodies may be involved in FOW project certification, a single classification society is responsible for all project phases. In this respect, classification would largely simplify the process. It minimizes potential analysis gaps between phases where different approaches are being used to evaluate a complex system, and helps increase accountability.

Ultimately, the choice between certification and classification rests with national authorities and project owners. National authorities along with FOW promoters like O&G majors and operators of renewable energy projects will shape the landscape of safety standards as FOW technologies mature and evolve. Straddling both sides of this line, BV has the ability to support its FOW customers, working with them to develop this fast-growing market.

This support is based on close relationships with national authorities, such as maritime flags and energy ministries, as well as a deep understanding of offshore technical challenges and a large range of offshore wind certification capabilities.

A Q&A with Seth Price, Vice President of Technology, Principle Power

What do clients expect from a certification company or classification society?

In these early stages of maturity, the FOW industry is at an important crossroads. Project developers and technology providers must be willing to work with certification and classification societies to develop rules that appropriately address the risks associated with the development and operation of a FOW farm. Although many similarities exist between the O&G industry and the FOW sector, there are some important differences (e.g., typically unmanned platforms, absence of hydrocarbon-based environmental impact, strong coupling between turbine and floater performance). These mean that it is paramount to converge upon the appropriate safety factors and risk consequence factors to ensure that the industry can continue its LCOE reduction trends while still keeping safety the number one priority for our projects.

It is also important that asset integrity data from the industry's early-stage, pre-commercial projects are shared in order to develop a robust classification society knowledge base. Design standards and recommended practices informed by real-world data will help ensure that all technologies deployed across the space are safe and reliable. The use of structural health monitoring and the inclusion of digital twins on FOW assets will continue to lead to more informed decision making.

BUREAU VERITAS MARINE & OFFSHORE **EDITORIAL TEAM**

(by alphabetical order)

EDITORS

Alexandra Beverley
Brand & Communication
Bureau Veritas Marine & Offshore

Nicholas Brown
Brand and Communications Director
Bureau Veritas Marine & Offshore

Alix Valenti
Editor
Valenti Communications & Consulting

CONTRIBUTORS

Special thanks for contributions from:

Pablo Necochea
Lead Developer Floating Segment
Vestas

Seth Price
Vice President of Technology
Principle Power

Bureau Veritas Contributors:

Matthieu Baert
Head of Renewable and Power section
Bureau Veritas Marine & Offshore

Olivier Cartier
VP Technical
Bureau Veritas Marine & Offshore

Stephan Ciniselli
Global Sales Director, Offshore Wind
Bureau Veritas Group

Claire-Julie Frelaut
Head of Hydrodynamic and Mooring team
within the Renewable and Power section
Bureau Veritas Marine & Offshore

Jean-Baptiste Gillet
Strategy and Advanced Services Director
Bureau Veritas Marine & Offshore

Joerg Gmeinbauer
Global Vice President, Power & Utilities
Bureau Veritas Group

Gary Hogg
Engineering, Risk & Environment service line lead
Bureau Veritas Solutions Marine & Offshore

Vincent Joly
Digital Solution Manager
Bureau Veritas Marine & Offshore

Eva Peño
Global Market Leader - OSV & Tugs
Bureau Veritas Marine & Offshore

Marie-Françoise Renard-Gondinet
Commercial Director Offshore
Bureau Veritas Marine & Offshore

Ignacio Romero
Global Technical Practice Lead, Offshore Wind
Bureau Veritas Group

Ulrike Therhaag
Global Technical Director, Power & Utilities
Bureau Veritas Group

James Vavasour
Group Marine Director/President
MatthewsDaniel

CONTACT

Jonathan Boutrot
Global Market Leader - Marine Renewable Energies
Bureau Veritas Marine & Offshore
jonathan.boutrot@bureauveritas.com

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**FOR MORE INFORMATION,
CONTACT BUREAU VERITAS MARINE & OFFSHORE**

8 cours du triangle
92937 Paris La Défense Cedex - France
+33 (0)1 55 24 70 00

marine-offshore.bureauveritas.com

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