Floating wind's next wave: from test beds to terawatts

Floating offshore wind is moving beyond demonstration projects towards commercial deployment. As developers look to exploit deeper waters beyond the practical limits of fixed-bottom foundations, attention is shifting from whether floating turbines can operate successfully to how they can be built, installed, monitored and maintained at commercial scale.

While floating technology has demonstrated its technical potential through a series of successful pilot projects, wider deployment will depend on much more than the platforms themselves. Port infrastructure, grid capacity, efficient installation methods and a detailed understanding of how floating assets behave throughout their operational life will all influence the pace of growth.

According to the Global Wind Energy Council, global offshore wind capacity reached 92.5 GW by the end of 2025, with fixed-bottom offshore wind continuing to dominate the market. Floating wind, by comparison, remains at an early stage of commercial development.

The opportunity, however, is significant. Much of the world's offshore wind resource lies in waters too deep for conventional fixed-bottom foundations, making floating technology one of the few practical options for unlocking these sites. Industry forecasts indicate that floating wind is expected to play an increasingly significant role in the offshore energy mix over the coming decades, provided costs continue to fall and supporting infrastructure develops alongside the technology.

What is becoming increasingly clear is that commercial success will rely not only on engineering innovation but also on the ability to collect and interpret high-quality operational data throughout the life of each asset.

Demonstrating the technology

Over the past decade, floating offshore wind has progressed from small-scale demonstration projects to larger commercial developments. Recent projects have shown that floating turbines can operate successfully in challenging offshore environments, even under demanding wind and wave conditions.

The next challenge is scaling deployment.

Many of the remaining barriers are not directly related to turbine technology. Instead, they concern the infrastructure required to manufacture, assemble, install and maintain floating wind farms.

Ports are one example. Floating foundations are typically assembled onshore before being towed to site, requiring deep-water quays, large assembly areas and heavy-lift cranes capable of handling extremely large components. Only a limited number of ports currently offer these capabilities.

Grid infrastructure presents another constraint. As larger projects move further offshore, suitable transmission capacity is essential to connect new generation to the electricity network. In many regions, grid availability has become one of the principal factors influencing project timescales.

This combination of infrastructure constraints creates a familiar challenge for an emerging industry. Investment in ports and grid connections often depends on a pipeline of future projects, while developers require

Hywind Tampen has been fully in operation since May 2023 and is currently considered one of the world's largest floating wind farms © Equinor

The three wind turbines for the Provence Grand Large project were first assembled on land and in the harbour, and then towed by tugboats to a position 17 km off the French coast

supporting infrastructure before committing to large-scale deployment.

Projects moving the industry forward

Several projects have helped demonstrate both the technical feasibility and the commercial potential of floating wind.

Equinor's Hywind Scotland, commissioned in 2017, became the world's first commercial-scale floating wind farm. Its five 6 MW turbines provided valuable operational experience in North Sea conditions and demonstrated that floating technology could generate electricity reliably in deeper waters.

Its successor, Hywind Tampen, entered operation in 2023 and remains one of the largest floating wind developments currently in service. The 88 MW project supplies electricity to offshore oil and gas installations, while also providing valuable experience in the deployment and operation of larger floating arrays. Lessons from Hywind Scotland contributed to lower project costs and improvements in installation and construction methods.

Elsewhere in Europe, Provence Grand Large became the first floating offshore wind farm in France and the wider Mediterranean when it was fully commissioned in June 2025. Located 17 kilometres off Port-Saint-Louis-du-Rhône, the project consists of three Siemens Gamesa turbines installed on tension leg platforms, a foundation concept adapted from the offshore oil and gas industry.

The 25 MW wind farm generates enough electricity to meet the annual consumption of approximately 45,000 people and provides an important reference project for floating wind deployment in Mediterranean conditions. EDF is also progressing plans for larger floating developments in the region.

Together, these projects demonstrate that floating wind technology is becoming increasingly mature. However, they also highlight the importance of gathering operational data that can be used to validate engineering assumptions, improve future designs and reduce long-term project risk.

The economics of floating wind

Although technical progress has been considerable, floating wind remains more expensive than conventional fixed-bottom offshore wind.

One reason is the operating environment itself.

Unlike fixed-bottom turbines, floating structures are continuously subjected to combined wind, wave and current loading. These forces influence the behaviour of the platform, tower, mooring system and export cables, creating a far more dynamic structural environment than is encountered on conventional offshore wind farms.

Designing systems capable of withstanding these conditions requires sophisticated engineering, extensive testing and detailed understanding of structural behaviour throughout the asset's operational life.

As the offshore wind industry scales up, larger projects, more efficient manufacturing and increasingly mature supply chains are expected to drive further cost reductions. However, reducing uncertainty around structural performance will also be important in lowering financing costs and improving investor confidence.

For developers and operators alike, this places increasing emphasis on measurement, monitoring and the collection of reliable operational data.

Four platform concepts, one operating challenge

Although floating wind technology continues to evolve, most projects are based on four principal platform concepts, each offering different advantages depending on water depth, seabed conditions and installation requirements.

Spar buoys achieve stability through a deep draft and substantial ballast, making them well suited to deep-water locations, although their size can present installation challenges.

Semi-submersible platforms distribute buoyancy across several columns, providing good stability while allowing assembly in relatively shallow ports before being towed offshore.

Barge platforms use a broad, shallow hull that simplifies construction but generally relies on active control strategies to manage platform motion.

Tension leg platforms (TLPs) are secured by taut mooring tendons that minimise vertical movement and provide excellent stability, although installation is more complex than for some alternative concepts.

Despite their differences, all four platform types operate in an environment where structural loads are constantly changing.

Wind, waves and ocean currents act simultaneously on the platform, while the rotating turbine introduces additional dynamic forces. Understanding how these combined loads affect the structure over time is essential for safe and economical operation.

Monitoring structural behaviour offshore

Floating structures present monitoring challenges that differ significantly from those of fixed-bottom turbines.

Mooring lines experience continuous variations in tension as platforms respond to changing sea states. Dynamic export cables flex repeatedly throughout their service life. Structural joints are subjected to cyclic loading that can contribute to fatigue, while the offshore environment accelerates corrosion and material degradation.

Because inspections offshore are both costly and weather dependent, operators increasingly rely on continuous monitoring to provide insight into asset conditions between physical inspections.

Structural health monitoring systems typically combine measurements from multiple sensor types, including accelerometers, strain gauges, inclinometers, displacement sensors and environmental monitoring equipment. Together, these provide a detailed picture of how the platform responds to real operating conditions.

Rather than relying solely on design calculations, engineers can compare measured behaviour with analytical and finite element models. This helps validate design assumptions, identify unexpected loading conditions and refine predictions of fatigue life.

The same information also supports maintenance planning. Detecting small changes in structural behaviour before they develop into more significant issues can reduce unplanned downtime and help operators target inspections where they are most needed.

Monitoring and control working together

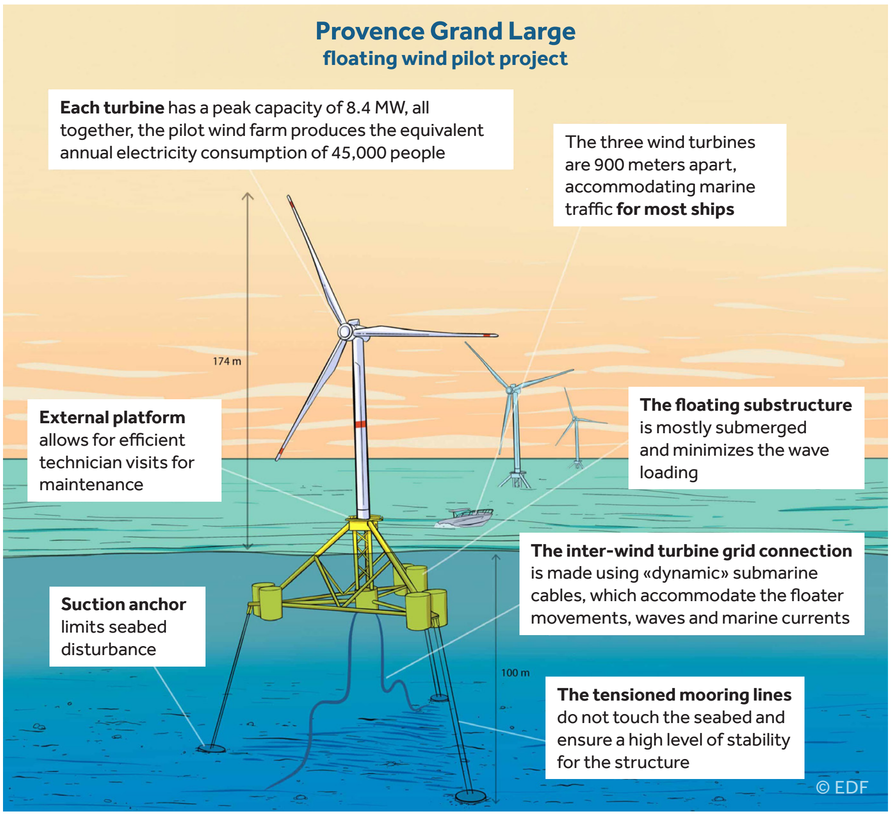
Measurement data plays an important role beyond condition monitoring alone.

Like conventional offshore turbines, floating wind turbines continuously adjust blade pitch and nacelle yaw to maximise energy production while limiting structural loads. Floating platforms may also incorporate additional control strategies to manage platform motion or optimise overall system performance.

These control functions rely on accurate, real-time information about the behaviour of both the turbine and its supporting structure.

Data from structural sensors, motion measurements, mooring systems and environmental monitoring therefore becomes part of an integrated operational picture, supporting both safe turbine operation and longer-term asset management.

As floating projects increase in size and complexity, integrating measurement, monitoring and control within a common architecture is becoming increasingly important for efficient operations.



Provence Grand Large is the first floating wind farm in the Mediterranean. The turbines are spaced 900 metres apart, allowing most ships to pass through the wind turbines unimpeded

Digital twins supporting asset management

One area receiving growing attention across the offshore wind sector is the use of digital twins.

A digital twin combines engineering models with live operational data to create a continuously updated representation of a physical asset. Rather than remaining a static design model, it evolves throughout the life of the project as new measurement data becomes available.

For floating wind, this allows engineers to compare predicted structural behaviour with actual operating conditions, improving confidence in design assumptions while helping identify areas where performance differs from expectations.

Digital twins can also support maintenance planning by assessing how environmental loading, operational history and structural response influence long-term fatigue. As operational datasets grow, these models become increasingly valuable for lifecycle management and future project design.

The growing role of artificial intelligence

Artificial intelligence is also beginning to support condition monitoring and asset management across offshore wind.

Rather than replacing engineering judgement, machine-learning techniques can help identify subtle patterns within large volumes of operational data that would be difficult to detect using conventional analysis alone.

Potential applications include recognising changes in mooring behaviour, identifying unusual structural responses, detecting emerging equipment faults and improving fatigue assessments by analysing trends across multiple operating conditions.

The effectiveness of these approaches depends on the quality and quantity of available data. As more floating projects enter commercial operation, expanding datasets are expected to improve the accuracy of predictive models and support increasingly sophisticated maintenance strategies.

Turning data into practical decisions

Continuous measurement generates large volumes of information, but the value lies in turning that information into decisions.

Integrated monitoring platforms bring together structural measurements, environmental data and turbine operating information, allowing engineers to assess asset condition within a single system rather than analysing multiple independent datasets.

For technology providers such as Bachmann electronic, this means combining measurement, automation and condition monitoring within a common platform. Integrating data from structural sensors, motion monitoring and turbine control systems enables operators to compare measured behaviour with engineering models while

The electricity generated by Provence Grand Large is transmitted via a 30-kilometre-long interconnection cable. 45,000 people are supplied with electricity by the floating turbines

supporting condition monitoring, maintenance planning and operational decision making throughout the asset's lifetime.

As floating wind projects continue to scale, this type of integrated approach is expected to play an increasingly important role in reducing operational uncertainty, extending asset life and improving the overall economics of offshore wind.

Learning from other offshore industries

One challenge for floating wind is the limited amount of operational data currently available. To address this, developers are increasingly applying transfer learning techniques, allowing analytical models developed using data from offshore oil and gas, maritime operations and engineering simulations to be adapted for floating wind applications.

This approach enables developers to make use of existing engineering knowledge while gradually refining models using operational data collected from floating wind projects themselves.

As commercial deployment expands, these models will increasingly reflect the specific characteristics of floating wind, improving both design confidence and operational performance.

The path to commercial scale

Floating wind has demonstrated that it can operate successfully in some of the world's most demanding offshore environments. The next phase of development will be less about proving that the technology works and more about delivering projects at the scale and cost required to support the global energy transition.

Achieving this will require progress across several fronts simultaneously. Investment in port infrastructure, grid connections, manufacturing capacity and specialist installation vessels will be just as important as continued advances in platform design.

Innovation is also continuing within the technology itself. Developers are exploring modular platform concepts that simplify fabrication and assembly, while new materials and manufacturing techniques are helping improve durability and reduce lifecycle costs. Advances in corrosion protection, high-performance concrete and additive manufacturing are all contributing to the evolution of floating foundation design.

Alongside these developments, operational data will continue to play an increasingly important role. Reliable measurement and monitoring allow engineers to validate new designs, improve understanding of structural behaviour, refine maintenance strategies and support more accurate lifecycle assessments.

As more commercial projects enter service, the industry's collective knowledge will grow, helping reduce uncertainty and supporting the wider deployment of floating offshore wind.

Looking ahead

Floating offshore wind is no longer solely an area of research or demonstration. Successful projects in the North Sea and Mediterranean have shown that the technology can operate reliably in deep-water environments, opening access to wind resources beyond the reach of conventional fixed-bottom foundations.

Significant challenges remain. Continued investment in infrastructure, supply chains, standardisation and project financing will all influence the pace of commercial deployment. At the same time, the industry will continue to build experience through larger projects operating under a wider range of environmental conditions.

Measurement and monitoring will be one part of this wider picture. By providing accurate information on how floating structures perform throughout their operational life, integrated monitoring systems support safer operation, improved maintenance planning and better-informed engineering decisions.

As floating wind moves from pilot projects towards commercial-scale deployment, combining robust engineering with high-quality operational data will help the industry deliver reliable, efficient and economically viable projects in deeper offshore waters.

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