sagentia
INNOVATION

WHITE PAPER

Remedies for the growing pains of floating offshore wind

AUTHOR
Francisco Siro - Head of Advisory

It's widely acknowledged that floating offshore wind installations could play a critical role in the energy transition. However, obstacles must be overcome before this aspect of wind power can reach its full potential.

Here, we identify major challenges and suggest how they might be resolved through innovative approaches and cross-sector learning. Five factors are covered: technical issues, industrialisation and supply chain, operations and maintenance, end-of-life, and asset management. They all impact the Levelized Cost of Energy (LCOE), or the price at which energy must be sold for a system to break even at the end of its lifetime. The cumulative benefits of addressing individual challenges could accelerate the maturation of floating offshore wind, aiding its transition to viable large-scale solutions.

Francisco 'Paco' Siro
Head of Advisory

Paco is a CEng, Fellow of the Institution of Mechanical Engineers, holds an MBA from Warwick Business School, and has a strong interest in energy transition and technologies related to the Internet of Things and additive manufacturing.

Financial predictions for offshore wind energy over the next decade make it an attractive prospect for innovation and investment. Global market size is projected to reach USD 31.4 billion by 2032 (up from USD 5.78 billion in 2022)[1]. Floating offshore wind is an emerging subcategory within this expanding market. It's attracting a high level of interest due to its ability to harness untapped offshore wind energy from deep waters. The world's first floating offshore wind farm, the 30 MW Hywind Scotland pilot park, has been operational for less than a decade yet achieves the highest average capacity factor of all UK offshore wind farms.

Nevertheless, floating offshore wind is still in its infancy and faces a steep learning curve as it scales from demonstration projects to gigawatt-scale developments. What's more, offshore wind, in general, suffered a setback in the UK last year with no bids submitted for Allocation Round 5 of the Contracts for Difference scheme (the UK government's main mechanism for supporting low-carbon electricity generation). A **Wind Europe** report suggests this was due to the strike price ceiling being too low. Having now been increased, it's expected that a significant volume of capacity will be awarded in forthcoming allocation rounds[2].

Other recent developments include the UK government's pledge to increase what it pays per MWh for offshore wind energy by more than 50%[3] and the **Octopus Energy** and **Tokyo Gas** USD 3.5bn offshore wind investment fund[4]. Floating offshore wind is not a UK or North Sea prerogative as projects have been considered across US, Europe and Japan.

So, operators with an interest in floating offshore wind have cause to be optimistic about its outlook for 2024 and beyond. To maximise the opportunity and get ahead of the game, it will be important to bridge the gap between demonstration and development as quickly and effectively as possible. Here, we explore five areas where challenges need to be resolved.

1. Technical issues

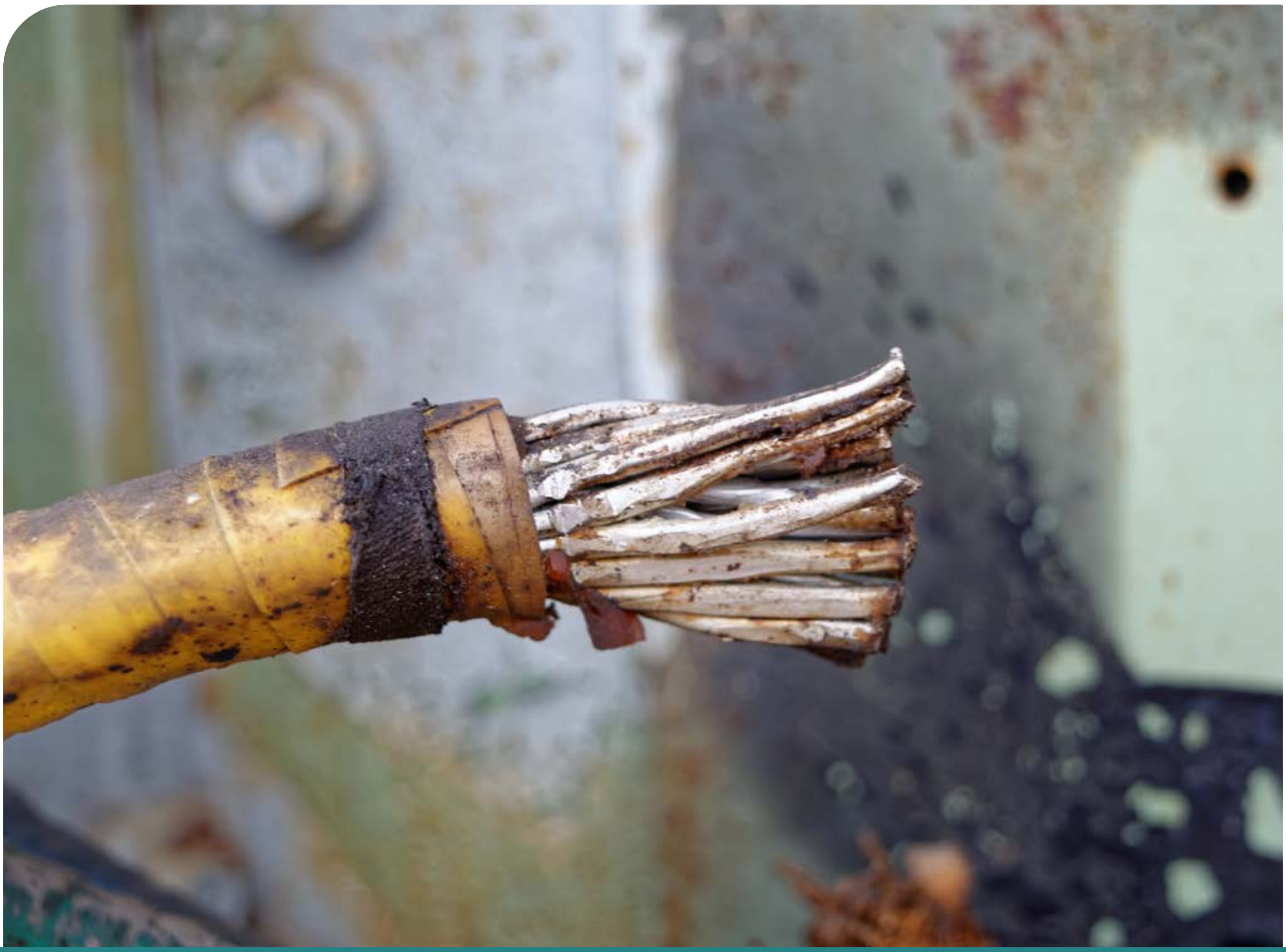
Publicly available reliability data for offshore wind is quite limited. Nevertheless, there are some well-known technical issues that must be resolved to optimise its LCOE.

A common cause of failure in offshore wind energy relates to the poor performance and reliability of subsea cables. There is not a single area of fault as issues may arise at any point of the project lifecycle, from design to operation. However, 70% of cable failures reported during operation are related to environmental conditions and third parties. Oscillation of floating platforms is likely to compound challenges linked to environmental conditions, so this is a key concern.

The erosion and delamination of turbine blades is another issue. As blades slice through the wind at high speed, fine particulates (i.e., dirt, dust, ice, snow, rain) impact their surface. Over time, these microscopic collisions combined with centrifugal forces and dynamic loads from vibrations cause erosion. Thin-walled components are also vulnerable to delamination caused by issues such as moisture ingress, temperature fluctuation, bonding failure, mechanical stress, and poor manufacturing quality.

Early main bearing failures in wind turbines are well documented too. Total cost of wind turbine gearbox replacement varies depending on factors such as the location, turbine type, and gearbox type. Nevertheless, it is invariably an expensive problem due to lost production, as well as the associated maintenance and component replacement costs.

We summarise measures which can mitigate these technical issues in Table 1.



Technical issue	Mitigation strategies
Blade erosion and delamination	Analyse new materials (nanomaterials, self-healing materials, anti-erosion coatings and bonding compounds) being developed in other sectors with better resistance and sustainability characteristics.
	Evaluate blades using Key Life Tests (KLT) aided by Dynamic Mechanical Analysis (DMA) tools to analyse legacy, current, and future patterns on critical parameters such as wind speed and direction, temperature, and humidity. Create a high-fidelity model to simulate 'real life' boundary conditions over whole life. Enhance blades with technologies that enable precise temperature and humidity control and prevent lightning damage.
	Identify and classify blade defects using image processing tools. Analysis of videos and photos taken during regular inspection can pinpoint emerging defects to enable proactive repair planning. Drones with advanced sensors can be used to assess actionable data in real-time, eliminating the need to turn the turbines off for manual inspections.
Bearing failures	Use DMA tools to analyse legacy, current, and future parameters affecting bearings. Incorporate these into design, testing, and validation processes to create high fidelity KLTs.
	Devise alternative designs for bearing systems, enabling rotation to ensure wear occurs over the entire 360-degree circumference rather than just a small portion of it.
Subsea cable issues	Design a KLT encompassing all predicted oscillations caused by platform movement and marine currents. Boundary conditions should incorporate past and current information from several sources.
	Incorporate robust quality assurance from initial concept design to installation and commissioning. A process adapted from Advanced Product Quality Planning (APQP), widely used in the automotive industry, can be applied to ensure the final product has high repeatability[5].
	Use non-destructive tests at vital stages of manufacture, installation, and commissioning. Consider the automatic harness testing used for safety-critical wiring systems in aerospace, defence, and rail to measure and record parameters like current continuity, resistance, short circuits, and installation resistance.

Table 1: Technical issues hindering floating offshore wind may be mitigated with methodical consideration of materials and operating parameters coupled with robust analysis and testing.

Addressing assembly issues

Technical issues impacting floating offshore wind are not limited to ongoing operations. The assembly of floating installations also presents major challenges.

Various techniques have been proposed to enable safe and cost-efficient assembly. These include the WindFlip barge concept, whereby a fully assembled turbine is loaded horizontally onto a spar-type platform and then transported to its final destination. Upon arrival, ballast tanks within the barge fill with water, causing it to sink stern-first, flipping the turbine 90 degrees, at which point it can be connected to mooring lines. Specialist engineering companies such as **GICON** and **Ideol** have designed their own assembly methods based on the original WindFlip concept.

Adjacent industries can also provide inspiration for overcoming engineering challenges posed by floating structures. Consider the 'walk to work' systems used in offshore oil and gas production to allow crew to move safely between transportation vessels and platforms in extreme weather conditions. Motion-compensated gangways use sensors to detect vessel motion, and then a hydraulic system counteracts the movement. These gangways have been tested in waves of up to 3.5m in height and the underlying technology could form the basis of innovative solutions for floating offshore wind.

2. Industrialisation and supply chain

According to the **Global Wind Energy Council** (GWEC), supply chain bottlenecks may impact wind power generation in every region of the world except China by the mid-2020s[6]. This, along with other factors detailed here, has created uncertainty, forcing developers to review project viability and in some cases halt development.

GWEC calls for ‘partnership not protectionism’ in addressing supply chain issues: “By working together, the industry and governments can create an environment that fosters innovation, investment and the development of a robust offshore wind supply chain. This approach is essential to meet the growing global demand for clean energy and make a significant positive impact on both the energy transition and environmental goals.”

One aspect of innovation that holds potential is the development and implementation of processes which facilitate mass production of components. At present, the supply chain is set up for low volumes, and this must be urgently addressed to cope with future demand. Mass production techniques will also have a positive impact on component quality and consistency, as well as lowering costs. Table 2 outlines techniques which could drive improvement.

Technique	Benefits
Standardisation and modularisation of components	Specifically designing components for manufacturing and sustainability facilitates repeatable, efficient construction.
Simulation tools	Applying simulation tools to the end-to-end process (manufacturing, transportation, logistics, assembly, and installation) can detect bottlenecks and identify processes for automation (e.g. welding, non-destructive testing, additive manufacturing). It’s also possible to discover ways to optimise installation and large component assembly.
Robust, holistic quality assurance processes	When quality assurance encompasses the entire supply chain, from concept to production, it’s easier to validate and document design changes. This enables automated non-destructive testing for cables or other critical components.

Table 2: A mass production mindset could mitigate the impact of supply chain issues.

At present, opportunities for standardisation are limited, partly due to variations in the concepts for floating foundations. As Figure 1 illustrates, three methods have been adapted from oil and gas installations:

Spar-Buoy: a plain- or multi- catenary system, with free-hanging chain mooring lines or a combination of chains and ropes that connect the substructure to anchors.

Spar-Submersible: a buoyant, semi-taut system using a combination of chains at the top and bottom with a rope mid-section on each line.

Tension Leg Platform: a taut system that uses rope lines connected under tension between substructure and anchors.

Floating offshore wind involves different loads and shallower conditions to floating offshore oil and gas applications, so there is still some uncertainty over which solution is most effective. The sooner this is resolved, the sooner component standardisation can begin.

Figure 1: Floating offshore wind foundation concepts.

3. Operations and Maintenance (O&M)

O&M accounts for up to 30% of the total life cost of offshore wind farms[7]. The figure could be even higher for floating offshore wind. Longer distances to shore and more hazardous weather conditions make it harder to access assets. This is a complex matter with no simple solution. However, investing in strategies to minimise on-site human inspection and maintenance could go a long way towards keeping O&M costs within tolerance. Autonomous and automated systems involving robotics and artificial intelligence (RAI) and internet of things (IoT) technologies hold great potential. Table 3 summarises available technologies which could be harnessed and further developed as part of integrated risk management for floating offshore wind.

Technology	Potential application	Detail
Unmanned Aerial Vehicles (UAVs)	Visual inspection of blades to monitor erosion, delamination, and other defects.	Advanced visual and radar sensing technologies such as Frequency Modulated Continuous Wave (FMCW) combined with AI solutions can recognise patterns and identify emerging defects.
Unmanned Underwater Vehicles (UUVs)	Visual inspection of subsea equipment for corrosion monitoring.	As with UAV inspection of blades, emerging degradation can be identified at an early stage. Research and innovation need to focus on AI-based systems for control and operation as well as the robotic technology itself.
Digital twins	Predictive modelling of degradation across the entire structure.	Harnessing advanced digital tools as part of O&M would support operational decision-making and intelligence-led mapping of maintenance schedules.
Continuous cable monitoring	Detection of cable corrosion and other degradation.	Low-frequency wideband sonar technologies are currently being tested for subsea cable applications.
IoT sensors	Capture of operational performance data across the entire structure.	Advanced sensor technology is integral to digital systems which support O&M decision making, as well as having the ability to trigger automated interventions where and when necessary.
Mooring load monitoring solutions	Real-time monitoring of mooring lines to identify issues which may reduce their lifespan.	Floating offshore wind structures' mooring lines are subjected to snap loads when sea conditions cause abrupt changes in tension. This can reduce the lifespan of mooring lines and requires ongoing monitoring.
Crawler robots	Blade repairs.	While these robots do present a risk of damage to the blade surface, the potential for remote maintenance means a trade-off may be acceptable.
Rail-guided inspection robots	Internal inspection.	These robots offer an effective way to inspect the interior of the nacelle (component housing). Their reach is somewhat limited, and they require a permanent structure within the nacelle, but they offer valuable remote visual inspection capabilities nonetheless.

Table 3: Existing technologies could be harnessed for the condition monitoring of floating offshore wind installations.

4. End of life

According to Offshore Renewable Energy (ORE) Catapult, more than 3.5GW of global offshore wind capacity will reach the end of its operational life by 2035[8]. Recently, end-of-life processes for turbine blades have faced particular scrutiny, especially regarding their disposal in landfill sites.

This raises the question of what decommissioning will look like for new floating offshore wind installations. Decommissioning is an intricate process requiring specialised deconstruction as well as strict compliance with environmental protection and waste disposal protocols. Operators are obliged to dismantle all components and restore the seabed to its original condition. In terms of turbine blades, several strategies can be harnessed to reduce negative environmental impacts, as summarised in Table 4.

Strategy	Detail
Recycle and reuse composite materials	Scale up the recycling and reuse of composite materials, for instance in boat applications. This will be essential to meet the industry commitment to stop landfill disposal of blades by 2025.
Adopt a 'sustainable by design' ethos	Leverage self-healing nanomaterials, sustainable alternatives to the manufacture of permanent magnets, and alternatives to carbon fibres.
Conduct holistic lifecycle assessment for recyclability	Devise strategies for reduction and reuse of waste during manufacture and use recycled material from other sectors. Also assess other sectors' recycling technologies and supply chain arrangements for potential replication.

Table 4: Practical measures should be put in place to support a safe and sustainable end of life for wind turbines.

5. Asset management

Ineffective asset management exacerbates many of the financial challenges of floating offshore wind production. However, risk management is greatly improved with a robust strategy which closely tracks asset performance, capital expenditure (CAPEX), and operational expenditure (OPEX). In this way it's easier to monitor – and therefore manage – overall LCOE. Early signs of deviation from the initial investment hypothesis can trigger corrective actions in good time. Table 5 summarises four key elements of effective asset management. A robust asset management strategy relies on holistic collaboration between different stakeholders, creating opportunities to drive down overall LCOE without eroding stakeholder profits.

Key elements	Detail
Comprehensive lifecycle cost model	A dynamic lifecycle cost model incorporates all costs incurred during the life of the asset. It must be regularly updated, incorporating relevant new information and enabling close monitoring of any cost deviations to the initial investment hypothesis.
Reliability growth plan	Created by the Original Equipment Manufacturers (OEMs) for different systems/assets (e.g. turbine, mooring, cables), a reliability growth plan feeds the lifecycle cost model and covers whole life, from commissioning to decommissioning. It should dynamically incorporate information from multiple internal sources such as supervisory control and data acquisition (SCADA), condition monitoring systems (CMS), and enterprise asset management (EAM) systems. Ideally, external information from similar assets should be incorporated too.
Asset management plan	Traditionally known as the maintenance plan, this encompasses regular maintenance and overhaul activities whether planned, condition-based, or run-to-fail (unlikely for these assets), as well as equipment refresh needs. It is closely connected to the reliability growth plan, lifecycle cost model, and the EAM system, which should automatically reflect any updates to recalculate costs and potential downtime as well as updating working orders and material planning for planned maintenance activities.
EAM system	This contains all information related to procurement/materials management, work management and contract management. It facilitates better control of the inventory, vendor contracts, and work orders, maintaining traceability of different components and systems while identifying normal and abnormal parts usage patterns.

Table 5: Effective asset management demands holistic, collaborative efforts to improve LCOE.

Airspace risk assessment for floating offshore wind

Floating offshore wind installations raise new considerations for aviation risk assessment planning. Sagentia Innovation's sister company Osprey Consulting, a specialist aviation consultancy, recently collaborated with NASH Maritime Limited to conduct a study on this matter for ORE Catapult[9]. Most potential effects uncovered were consistent with those already documented for offshore wind farms. However, the study identified some key exceptions:

- Management of wet storage sites – Floating offshore wind introduces new potential effect areas in coastal waters where wind turbines might be temporarily moored during construction or maintenance. Coastal/littoral aerodromes have not typically been directly impacted by offshore windfarms. The use of wet storage imposes new potential effects to aviation receptors which have not previously been assessed in project applications due to uncertainties on the likely locations of wet storage sites and proximity to aerodromes.
- Assessment of the safety of towage operations – The potential frequent movement of floating offshore wind turbines introduces new risks both around project sites and coastal/littoral aerodromes. There is a greater potential for conflict with vessel traffic, wind turbines in transit and aviation receptors.
- Changes to site layout – Maintenance activities may result in temporary removal of floating wind turbines from the array area, resulting in gaps and changes to geometries which are difficult to manage, change site lighting and marking and might increase aviation risk.
- Cumulative impacts – The significant pipeline of floating offshore wind projects is likely to result in greater prominence of cumulative effects, and existing approaches through project-specific assessments are perhaps not well suited to regional scale issues.

Strategies to mitigate these issues include improved planning, risk assessment, and management of storage sites to minimise adverse impacts. Solutions might involve updating existing guidance, developing new guidance, and conducting separate studies to help consolidate and centralise the management of wet storage.

How Sagentia Innovation can help

It won't be easy to unlock the full potential of floating offshore wind. In addition to the challenges covered here, operators must gain government approval and connections to the grid. Nevertheless, companies with the skill and tenacity to succeed stand to reap significant rewards. Here at Sagentia Innovation, we can help you overcome challenges more quickly by leveraging:

- Technology evaluation expertise to determine transferability across sectors and applications.
- Proven approaches to accelerate development of complex products through all technology readiness levels (TRLs) to commercialisation.
- Experience in the development of drones and robotic equipment to perform remote maintenance and complex procedures.
- Cost management expertise for large, long lifespan assets in collaboration with our sister company TP Group.
- Experience running industry networks to support collaboration and address common technical challenges hindering offshore energy production.

Contact **info@sagentiainnovation.com** to discuss how our science, engineering, and energy sector specialists can help you navigate and mitigate challenges for quicker progress in floating offshore wind.

References

1 Offshore Wind Energy Market, Precedence Research, October 2023, https://www.precedenceresearch.com/offshore-wind-energy-market#:~:text=The%20global%20offshore%20wind%20energy%20market%20size%20was%20reached%20at,the%20rest%20of%20the%20Europe

2 Wind energy in Europe: 2023 statistics and the outlook for 2024-2030, Wind Europe, 28 February, 2024 https://windeurope.org/intelligence-platform/product/wind-energy-in-europe-2023-statistics-and-the-outlook-for-2024-2030/#findings

3 Price paid for offshore power to rise by over 50%, BBC News, 16 November 2023 https://www.bbc.co.uk/news/business-67430888

4 Octopus Energy launches £3bn offshore wind fund with Tokyo Gas, Power Technology, 20 November 2023 https://www.power-technology.com/news/octopus-energy-3bn-offshore-wind-fund-tokyo-gas/

5 APQP4Wind https://apqp4wind.org/about-apqp4wind

6 Global offshore wind report 2023, Global Wind Energy Council https://gwec.net/wp-content/uploads/2023/08/GWEC-Global-Offshore-Wind-Report-2023.pdf

7 Operation and maintenance costs of offshore wind farms and potential multi-use platforms in the Dutch North Sea, Springer Link, 7 April 2017 https://link.springer.com/chapter/10.1007/978-3-319-51159-7_4

8 End-of-life planning in offshore wind, Catapult Offshore Renewable Energy, April 2021 https://ore.catapult.org.uk/wp-content/uploads/2021/04/End-of-Life-decision-planning-in-offshore-wind_FINAL_AS-1.pdf

9 Enhancing Aviation Environmental Impact Assessment (EIA) for Fixed and Floating Offshore Wind Farms, Osprey Consulting Services https://ospreycsl.co.uk/casestudies/enhancing-aviation-environmental-impact-assessment-eia-for-fixed-and-floating-offshore-wind-farms/

About Sagentia Innovation

Sagentia Innovation provides independent advisory and leading-edge product development services focused on science and technology initiatives. Working across industrial, chemical, energy, food and beverage, and consumer markets, Sagentia Innovation works with start-up disruptors through to world leading brands to extract maximum value from R&D and innovation investments.

sagentia.com/innovation

For further information visit us at:

sagentia.com/innovation or
email info@sagentiainnovation.com

Sagentia Ltd
Harston Mill
Harston
Cambridge
CB22 7GG
UK

Sagentia Ltd
First Floor
17 Waterloo Place
London
SW1Y 4AR
UK

Sagentia Inc
1150 18th Street
Suite 475
Washington
D.C. 20036
USA

sagentia
INNOVATION