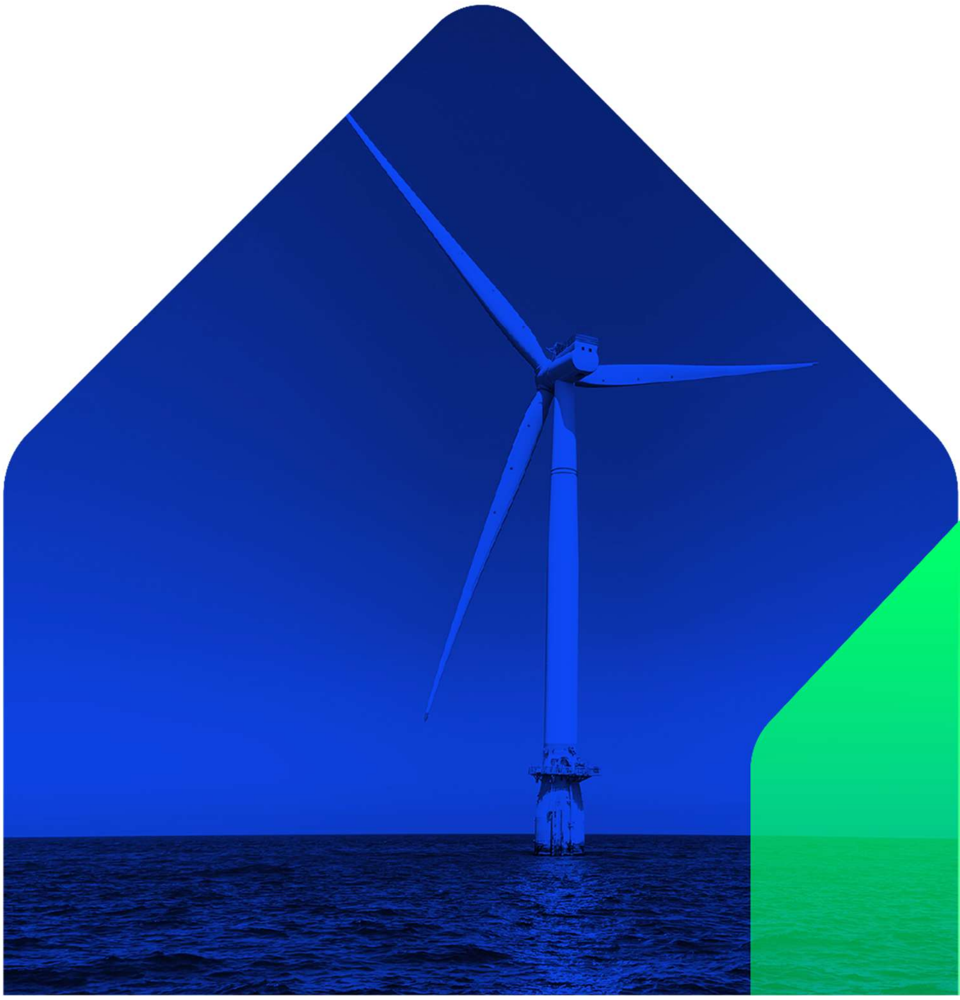
FLOATING WIND JOINT INDUSTRY PROGRAMME

Prevention of marine growth

May 2025



Contents

Authors:

Michael Archer
Associate, the Carbon Trust
michael.archer@carbontrust.com

Luisa Amorim
Manager, the Carbon Trust
luisa.amorim@carbontrust.com

Maria Salta
Project Manager/Senior Researcher, Endures

Nanni Noël-Hermes
Senior Researcher, Endures

Ryan Abela
Naval Architect. KENT

Acknowledgments

The Carbon Trust wrote this report based on an impartial analysis of primary and secondary sources, including expert interviews.

The Carbon Trust would like to thank everyone that has contributed their time and expertise during the preparation and completion of this report. Special thanks goes to: Amog, University of Aberdeen, University of Nantes, Scottish Association for Marine Science (SAMS), Fugro, BP, DNV, Bekaert, FlexiClean.

Introduction

The Prevention of Marine Growth (PoMG) project was delivered by Endures in collaboration with KENT on behalf of the Floating Wind Joint Industry Programme (Floating Wind JIP).

Marine growth, also known as biofouling, can significantly affect the performance and structural integrity of offshore assets and its effect is still relatively unknown for large-scale floating wind assets. In the worst-case scenario, it could exacerbate fatigue and ultimate loads on floating wind systems due to factors such as added weight, altered geometry, and changes to surface texture. Over time, this can lead to significant damage, increased downtime, and higher operation and maintenance (O&M) demands for large-scale commercial floating wind arrays.

The PoMG project aimed to improve understanding and quantification of the effects of marine growth over the lifespan of commercial floating wind assets. The focus of this project was to predict marine growth and its global variability, with the goal of enhancing the understanding of its cumulative impacts throughout a project's lifecycle. The project also reviewed current best practices for design, mitigation, and management strategies. Insights from other marine industries, such as oil and gas, were leveraged to address challenges associated with marine growth in the context of large-scale commercial floating offshore wind developments.

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Project objectives

1. Map typical marine growth on various materials and surfaces and identify any variation dependant on geographical locations.
2. Understand the applicability of approaches and standards from other marine sectors, such as oil and gas, to floating offshore wind.
3. Investigate current standards related to marine growth and, where applicable, identify industry needs and knowledge gaps to assist in the development of commercial floating wind projects.
4. Identify technology solutions, focusing on passive solutions, that reduce marine growth over the lifetime of an asset.
5. Provide an understanding of any additional need for supply chain servicing specific to the floating wind sector.
6. Investigate the varying driving factors of different asset makeup such as foundation types, mooring and cable configurations, and varying geographical location.

Methodology

Literature review and stakeholder engagement

A literature review and stakeholder engagement were conducted across the offshore wind industry. This aimed to assess the existing data, approaches and standards available in the public domain, and its applicability to the offshore wind industry. The approach adopted is outlined below:

- Reports, industry standards, case studies, and publicly available data were gathered from reliable sources such as academic publications, government documents, and industry white papers;
- Representatives from renewable energy systems (with a focus on floating offshore wind) were engaged through a series of four stakeholder engagement workshops (SEW), including academic experts, certifiers, logistics experts, fouling-control companies and mooring systems experts on biofouling. Key knowledge gaps were identified during the SEWs, and the information collected was organised into topic areas to systematically address the key project objectives. This included categorising data into topics such as environmental factors, design practices, and regional variability.

Critical analysis and modelling approach

The credibility, relevance, and limitations of the information collected were analysed and cross-referenced with findings from different sources to ensure robustness and to highlight knowledge gaps.

The stakeholder engagement and literature review informed the inputs for the modelling process, which drove the decision on marine growth levels and types, as well as foundation types, to be analysed and assessed over the lifetime of an offshore floating wind asset.

The modelling approach was as follows:

- A coupled hydro-aero-elastic 15MW turbine model with two irregular sea states (representing the requirements of FLS and ULS checks) was used as part of an assessment of eight mooring configurations (catenary, semi-taut and taut, varying between 70-1000m), across two floater types (TLP and Semi-submersible foundation design), and including inter-array cables.
- Derived load cases were developed, considering marine growth levels and types, water depth, mooring type, and foundation type. Four levels of marine growth were analysed for each configuration (no marine growth, low, medium and high). Marine growth was considered on the floater, mooring lines and inter-array cables.
- Mooring line tensions and floater motions from time-domain analysis were compared to understand the effect of marine growth levels against the base case, with no marine growth.

Comparative studies

Lessons learned and best practices from analogous industries or projects were incorporated to provide context and broader applicability of findings. This included monitoring approaches, modelling findings, and marine growth removal methods.

Marine growth mapping

A map of typical worldwide marine growth variation was developed, based on available geographical data, and considering the growth effect on various types of materials and surfaces typically used in floating foundations, mooring systems, and dynamic cables.

Synthesis of findings

The key insights from the previous steps we used to form a response to the project objectives. This included summarising trends, identifying challenges, and proposing recommendations for next steps.

The synthesis of the project's findings was based on the process and typical effects of biofouling on man-made structures, outlined in Figure 1 below. As part of the process, the types of biofouling considered and not considered in current modelling and guidelines were identified, and the effects were assessed.

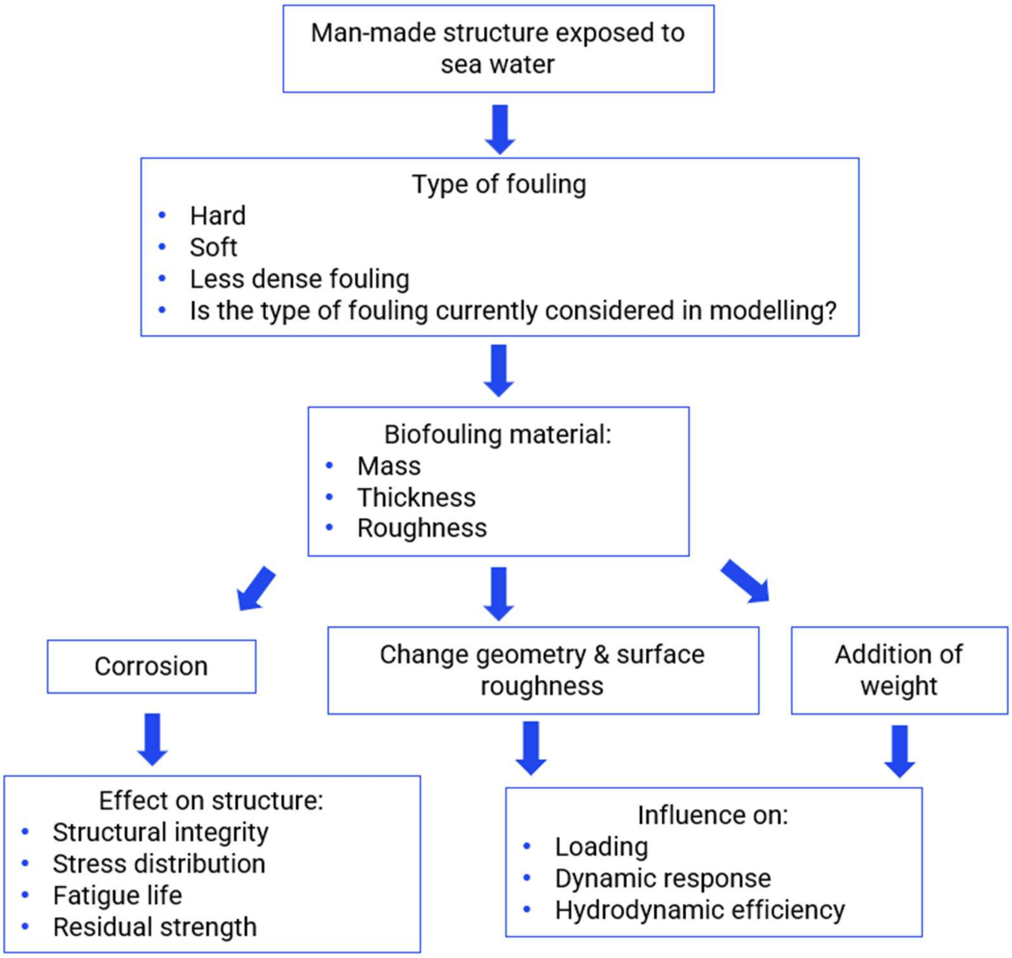

Figure 1. Effect of biofouling on man-made structures exposed to seawater environment.

Key findings

1 Current relevant standards for offshore wind recommend considering marine growth in design calculations (e.g. increase in hydrodynamic drag coefficient, mass and buoyancy) however, current data are limited and lacks detail.

- Standards for offshore wind structures, such as DNV-OS-J101 or DNV-OS-E301, as well as standards from other offshore industries like ISO19901 from the oil and gas sector, recommend accounting for biofouling in design calculations.
- These standards consider increases in hydrodynamic diameter, mass, buoyancy, and variations in the hydrodynamic drag coefficient due to marine growth-induced roughness. Importantly, these standards use information from a single source with data from only two sites in the North Sea, lacking taxa -specific data. This results in limited insights into the impact of relevant taxa like mussels, barnacles or algae.
- While existing standards emphasise the importance of obtaining site-specific marine growth profiles, including recording and measuring marine growth, they do not provide detailed guidelines for conducting surveys for marine characterisation and may lead to inaccurate or conservative assessments of marine growth in specific environments.

2 Parameters essential to measure marine growth, including biomass and surface roughness, are missing or inconsistent.

- Marine growth analyses of an offshore structure require data on parameters such as biomass, thickness of fouling, and surface roughness. However, biomass or surface roughness datasets are often missing, with gaps or limited to specific locations or regions.
- Published data on fouling thickness should be expressed as density, in kg/m3, to align with the models. However, it is often reported in kg/m2, which poses difficulties when adjusting mass as marine growth thickness changes throughout the water column.

3 Soft fouling such as algae, is not typically included in calculations, leaving its impact unknown.

- From the limited data available, only hard fouling was found to be characterised by thickness, roughness and biomass, while soft fouling, such as algae (e.g. kelps), is typically excluded from calculations.
- Literature and guidelines rarely distinguish between hard and soft fouling when describing parameters like thickness, drag coefficient, or roughness. Therefore, the impact of soft fouling is unknown.

4 Available data on marine growth are highly site-specific and limited to the upper few meters of surface water.

- Typical values for density, surface roughness, and site-specific formulas for thickness and drag coefficient are mainly available for the North Sea.
- Engineers often rely on North Sea standards related to the oil and gas industries, which can lead to over-protection or failures due to inaccurate calculations. Marine growth data available is typically limited to the top few meters of surface water, neglecting deeper zones.

5 **Marine growth can have a significant negative impact on inter-array cable 'lazy-wave' profiles, with the effect being most pronounced in shallow water depths.**

- Static calculations indicate that marine growth can significantly impact the lazy-wave profile of the inter-array cable. Particularly for the shallow water configurations, where the inter-array cable 'lazy wave' shape will not be maintained following the addition of marine growth. This is due to additional marine growth altering the cable's buoyancy profile, causing it to sink to the seabed and create touchdowns on either side of the cable's buoyant section.
- In shallower waters, inter-array cables are more sensitive to weight and buoyancy changes than inter-array cables in deeper waters. Shallow waters lead to reduced water columns, which limits lazy wave profile and results in a smaller bending radius. Additionally, marine growth is found to be much more pronounced in the top 30m of the water column.

6 **Marine growth can result in significant increases to inter-array cable tensions, with the effect being most pronounced in shallow water depths.**

- Inter-array cables are designed to not interfere with the mooring system and therefore produce little to no lateral load. This means that the tensions exhibited by inter-array cables are primarily due to the cable's self-weight and buoyancy characteristics. Across all configurations, an increase in marine growth resulted in altered cable characteristics, leading to greater inter-array cable tensions.
- As inter-array cable tensions are a product of the cable's self-weight, the greater the cable length the greater the tension. Therefore, increases in inter-array cable tensions appear to be more pronounced in shallow waters as the marine growth weight is proportionally greater when considering a shorter cable. This is further emphasised by the marine growth profile through the water column, as marine growth adherence reduces with an increase in depth.

Industry needs/innovations

1 **It is necessary to conduct natural time-series of marine growth to address prediction uncertainties.**

- Commencing with natural time-series (NTS) observations of biofouling growth, including detachment events, will help reduce and eventually eliminate prediction uncertainties.
- Monitoring these processes over extended periods, researchers can gain insights into the dynamics of biofouling and develop more accurate predictive models.

- Accurate predictive models can enhance the reliability and efficiency of renewable energy installations.
- Formulating correlations between environmental factors, materials, and the occurrence of biofouling species relevant to renewable energy development is also crucial. Understanding these relationships can inform the selection of materials and the design of structures to minimise biofouling impacts and improve operational longevity.

2 **The industry must create innovative tools to fill the knowledge gaps in marine growth parameters that are necessary for accurate predictions.**

- Understanding the weight of biofouling and its impact on buoyancy and stability is crucial for maintaining the integrity of marine structures.
- It is essential to determine if the weight of biofouling is evenly distributed along cables or concentrated in certain areas, which could pose additional risks.
- Another important consideration is the timeline for a particular species to dominate a biofouling community, as this can affect maintenance schedules and the overall health of the ecosystem.
- The influence of electromagnetic fields on the growth rate of biofouling organisms is also a key area of investigation, as it may inform the design and placement of underwater cables and structures.

3 **Specific floating wind guidelines and standards should be developed and tailored based on NTS monitoring protocols, mitigation strategies studies and analysis.**

- Standards need to be adjusted to better serve new custom-made design guidelines, instead of adopting practices developed for the oil and gas industry.
- The unique conditions and challenges faced by the renewable energy sector require tailored solutions that address specific biofouling issues, rather than relying on protocols that may not be fully applicable.
- A shift towards bespoke guidelines will ensure that the renewable energy industry can effectively manage biofouling, optimise performance, and contribute to the broader goals of sustainability and environmental protection.
- Through these concerted efforts, the industry can advance its technological capabilities and achieve greater resilience against the challenges posed by biofouling, such as maintaining the inter-array cable’s profile and performance.

ABOUT THE FLOATING WIND JIP

The Floating Wind Joint Industry Programme (Floating Wind JIP) is a collaborative research and development (R&D) initiative between the Carbon Trust and 17 leading international offshore wind developers: bp, EDF Renouvables, EnBW, Equinor, Kyuden Mirai Energy, Ørsted, Ocean Winds, Parkwind, RWE Renewables, ScottishPower Renewables, Shell, Skyborn Renewables, SSE Renewables, TEPCO, Tohoku Electric Power Company, Total Energies and Vattenfall.

The primary objective of the Floating Wind JIP is to overcome technical challenges and advance opportunities for commercial scale floating wind. Since its formation in 2016, the programme scope has evolved from feasibility studies to specific challenges focusing on:

- Large scale deployment
- De-risking technology challenges
- Identifying innovative solutions
- Cost reduction

Stage 3 of the Floating Wind JIP commenced in 2022 and projects are expected to run until early 2027. With several commercial scale floating offshore wind farm projects in design phase and having the ambition to be commissioned by 2030, the industry needs to address several challenges. The 17 Floating Wind JIP partners agreed on six research areas where further understanding and advancement is required to reach full commercialisation of floating offshore wind projects.

Electrical systems	Mooring systems	Logistics	Windfarm optimisation	Foundations	Asset Integrity and monitoring

This Prevention of Marine Growth project addresses the ambitions of the Mooring Systems and Foundations research areas:

Mooring systems

1	Define optimal mooring layout and anchoring for different challenging environments and model subsea interactions.
2	Better understand the integrity of mooring lines through improved monitoring techniques.
3	Understand how geographical and material selection affect the availability and manufacturing capabilities of different mooring and anchoring solutions.

Foundations

1	Understand how different materials and manufacturing processes affect the commercialisation of different floater designs.
2	Improve the modelling and design process for integrated floater designs.
3	Improve the understanding of foundation design and performance.

The Stage 2 summary reports can be found here: Phase I, Phase II, Phase III, Phase IV and Phase V.

ABOUT THE CARBON TRUST

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Our mission is to accelerate the move to a decarbonised future. We are your expert guide to turn your climate ambition into impact.

We have been climate pioneers for more than 20 years, partnering with leading businesses, governments and financial institutions to drive positive climate action. To date, our 400 experts globally have helped set 200+ science-based targets and guided 3,000+ organisations and cities across five continents on their route to Net Zero.

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+44 (0) 20 7170 7000

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Published in the UK: 2025