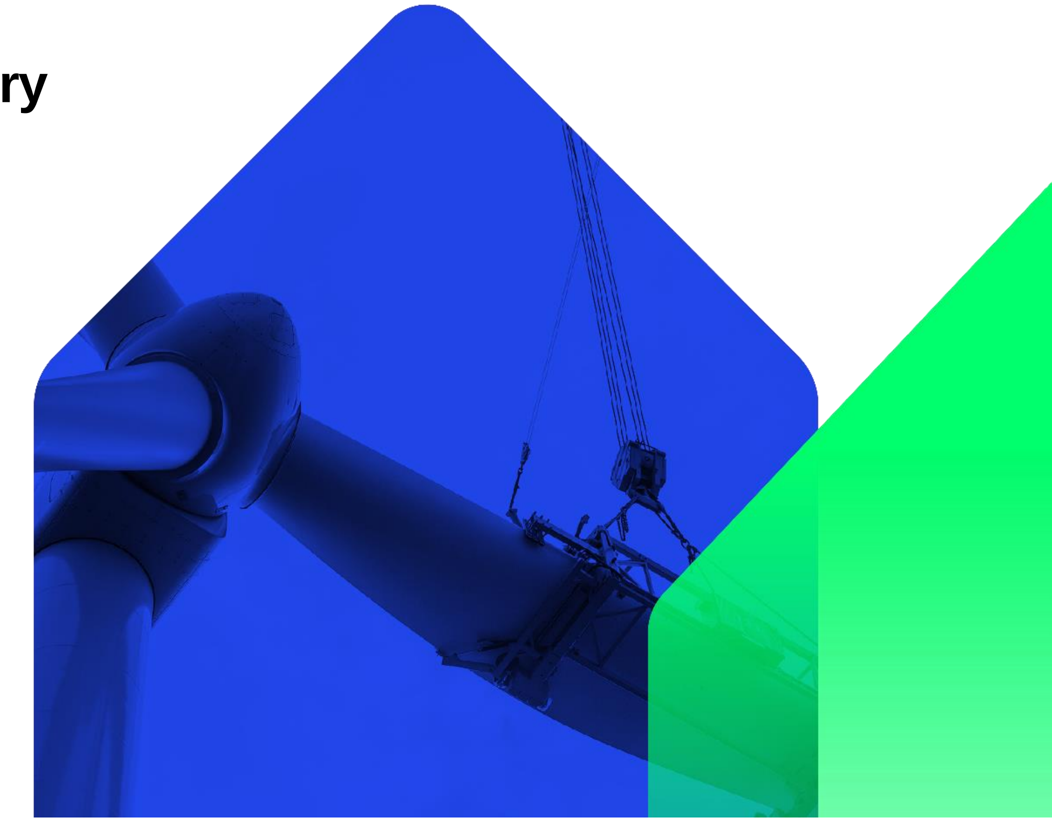
FLOATING WIND JOINT INDUSTRY PROGRAMME

Major Component Exchange with Self-Hoisting Cranes

Project summary

September 2023



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Cover image courtesy of Rampion Offshore Wind.

Introduction

Major component exchange for floating offshore wind (FOW) turbines is considered an expensive and challenging operation. A large proportion of FOW site locations will be located in deep waters, where conventional jack-up vessels cannot be used.

One viable solution to undertake a major component exchange is to tow the FOW substructure to the port (TTP), to undertake the exchange in sheltered conditions. There are many challenges associated with a successful TTP operation, including the large towing distances to FOW arrays, costs associated with onshore cranes and downtime losses due to weather constraints. Another solution is to mobilise semi-submersible heavy lift vessels, however, the expensive charter costs and potentially limiting crane lift capabilities, mean this is unlikely to be a long-term competitive solution.

An alternative offshore maintenance strategy is to use self-hoisting, turbine mounted cranes. The benefit of using a self-hoisting crane is that the crane follows the relative motions of the turbine. The final crane height is provided by the turbine structure, rather than a heavy lift vessel, meaning less expensive vessels (with lower crane lifting capabilities) can be used. However, there are still some challenges associated with using self-hoisting cranes, including:

- The logistical challenge of transferring the crane between the service vessel and the turbine;
- The need to assemble and disassemble the crane system on each turbine requiring maintenance;
- The need for design modifications or retrofits to the turbine, tower, and/or substructure, which may involve the need for system recertification.

The Floating Wind Joint Industry Programme (JIP) previously assessed technology options surrounding major component exchange including self-hoisting cranes or climbing cranes. This Major Component Exchange with Self-Hoisting Cranes project (SHC), delivered by OWC and WavEC, built on this previous research.

This summary report outlines the project's key findings based on the objectives and highlights future requirements or needs for the industry.

Project objectives

1. Identify solutions to conduct onsite major component exchange of Wind Turbine Generator (WTG) nacelle components without relying on large heavy lift vessels or towing a substructure to port.
2. Examine different technology concepts for major component exchange and assess feasibility considering technology, risk, cost and operational requirements.
3. Detail the steps needed to achieve commercial deployment of these technology concepts.

Methodology

The Major Component Exchange with Self-Hoisting Cranes (SHC) project was undertaken to further understand self-hoisting crane technology options, their feasibility, barriers to commercial deployment and industry innovation needs.

Eighteen separate self-hoisting crane concepts were identified and assessed against a series of technology, maturity and FOW suitability criteria. A number of these concepts were subsequently shortlisted, and an in-depth assessment was carried out including:

1. Assessment of technology scalability.
2. Development of detailed method statements.
3. Development of storyboards to illustrate key operational steps.
4. Identification of main hazards and risk mitigation approaches.
5. Definition of the main Infrastructural requirements to carry out operations.
6. Weather window assessment for a generic replacement operation utilising self-hoisting cranes.
7. Numerical simulation of critical operations.
8. Comparison of total exchange duration.

Several assumptions were made during the in-depth assessment, including:

- 10 MW and 15 MW reference turbines provided by the Floating Wind JIP were used as a baseline.
- All four main floating substructure types; semi-submersible, barge, Tension Leg Platform (TLP) and Spar were considered.
- A primary focus was made on the 15 MW semi-submersible substructure.
- Both permanent and temporary working decks were assumed.

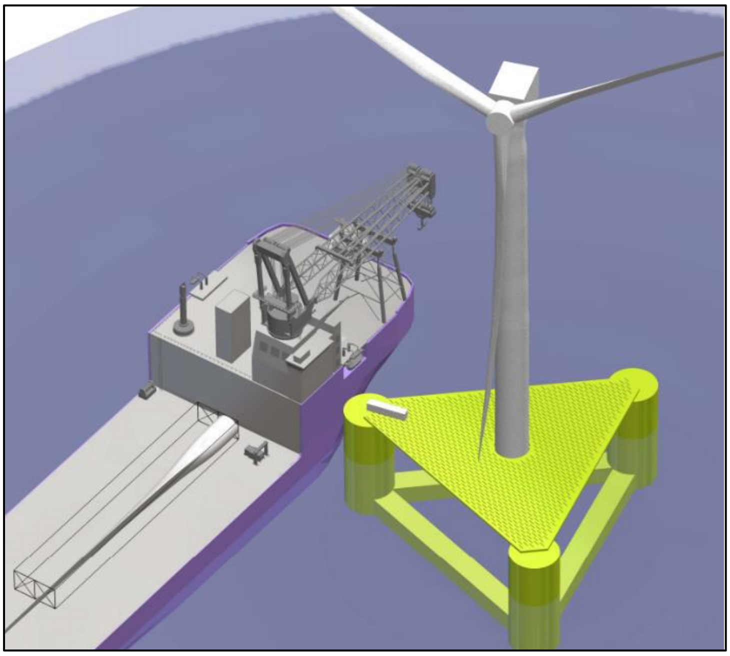


Figure 1: Storyboard development, OWC and WavEC.

Key findings

1

The inclusion of working decks on the floating substructure is strongly recommended to facilitate self-hoisting crane use.

- The use of a working deck as an intermediate lifting point simplifies floating-to-floating lifting operations. This also minimises the self-hoisting crane boom requirements and potential bending moments on the tower.
- The temporary working deck should have connection points to attach and secure blade cassettes and/or drive train components.
- One benefit of self-hoisting crane concepts is that smaller vessels can be utilised. Additional weight from the self-hoisting crane and components will require in-depth numerical assessments to determine the hydro-dynamic stability of the substructure. Self-ballasting capabilities will be beneficial to compensate for this.
- The use of self-hoisting cranes also introduces a new level of operational complexity and consequently, new health, safety and environmental (HSE) challenges, which need to be minimised. Measures such as twist-lock sockets to enable the securement of larger components are recommended.

2

On-site preparations play a significant role in the overall duration of offshore work activities and consequently, overall cost.

- For most technologies, the offshore work associated with installing the self-hoisting crane on the turbine is the primary factor contributing to the total operation duration.
- Demobilisation of the self-hoisting crane from the turbine to the vessel was found to be the second largest contributor to total operation duration.
- Simplifying assembly procedures could substantially reduce the on-site preparation work required, thereby reducing the downtime losses and associated costs caused by wind turbine generators having to remain offline during operation and maintenance work.
- Each self-hoisting crane technology was assessed using detailed method statements, as indicated in Figure 2. This described the sequence of tasks, durations and related limiting weather conditions.

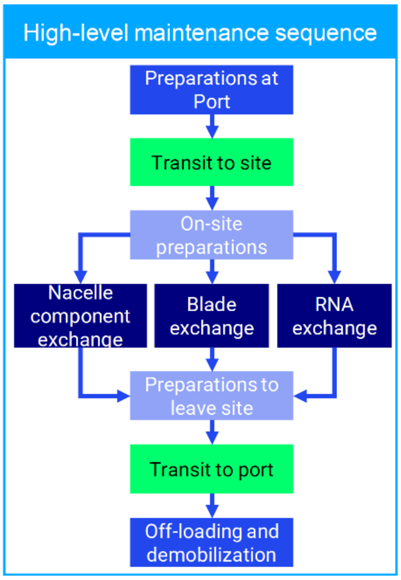


Figure 2: Generic sequence of on-site maintenance of large offshore wind components, delivered by OWC and WavEc.

3 Both geared and direct drive turbines will present challenges in relation to using self-hoisting cranes for major component exchange.

- Self-hoisting cranes could be used across both direct drive and geared wind turbines, to replace major components such as blades, generators and bearings as well as drivetrain components on gearbox turbines.
- However, for direct drive wind turbines, replacement of the generator and main bearing would be more challenging to undertake offshore.
- For direct drive turbines, consideration should be given to modular construction (e.g., generator segments) to facilitate fewer challenging lifts in the offshore environment.
- Furthermore, self-hoisting crane concepts that interface with the top of the turbine mainframe may necessitate additional interface considerations when used with a direct drive turbine.

4 Integrating different types of substructures is a key consideration in using self-hoisting crane technology for major component exchange.

- The typology of the FOW turbine substructure plays a fundamental role in the feasibility of the major component exchange whilst using self-hoisting crane technologies. Deck space attached to the turbine or floating substructure has the potential to be a limiting factor. As many substructures are not typically designed with suitable working decks, temporary working decks could be a solution.
- Self-hoisting crane developers have not expressed any compatibility concerns with specific substructures, though have stated their technologies may be better suited to specific substructure types. Substructures with larger surface areas and ballasting capabilities, to accommodate additional weights, could be at an advantage.
- Interface standardisation could support the advancement of self-hoisting crane technology in the market.

Figure 3: Reference substructure designs for the Floating Wind JIP.

Industry needs and innovations

1 Demonstration programmes are a crucial next step to bring self-hoisting cranes to market.

- Commercial-scale FOW farms are forecast to be in operation by the 2030s and will require significant global capabilities to carry out the required operations and maintenance (O&M) procedures. So far, few concepts have undertaken offshore testing, which will be fundamental for understanding the restrictions of O&M capabilities at a commercial scale.
- While successful onshore tests are important for self-hoisting crane development, offshore testing is necessary to increase industry confidence and refine O&M strategies. Offshore testing and validation steps are likely to look different for the varying self-hoisting crane technologies, as their maturity levels rise, though overall steps could include a demonstration of bottom-fixed offshore wind turbines followed by a demonstration of floating offshore wind turbines.
- Key Performance Indicators could include total operation durations, operational success rates, limiting environmental conditions, feedback from operators, and self-hoisting crane kinematics.

2 Enhancing crane reach and lifting capacity must be upgraded to accommodate next-generation wind turbine generators.

- Existing self-hoisting crane technologies were historically designed for onshore wind operations, with smaller turbines and consequently a lower lifting capacity requirement. The next generation of floating offshore wind turbines will be 15 MW+ and in turn, will require larger lifting capacity and crane reach.
- The commercialisation of self-hoisting crane technologies for major component exchange on 15 MW wind turbines will largely depend on the ability to increase crane lifting capacity. To facilitate O&M operations and major component exchange for turbines up to 15 MW, upgrades are required to the lifting capacity and crane reach of existing solutions.

Figure 4: Turbine scaling, provided for the Floating Wind JIP by Ramboll.

3 An increase industry collaboration is required to standardise and optimise self-hoisting crane designs.

- Industry collaboration will be essential to accelerate the commercial deployment of self-hoisting cranes for floating wind turbines.
- It is well understood that in most cases, a collaboration between self-hoisting crane developers and turbine manufacturers is critical to their development including collaboration with substructure designers. The continued support of turbine manufacturers could facilitate design optimisation, broader adoption and market entry for self-hoisting cranes.
- Engaging multiple stakeholders to advance self-hoisting crane design standardisation could prevent early commitment to a particular self-hoisting crane technology, thus ensuring open market competition between self-hoisting crane technologies. It may also help to avoid higher manufacturing costs due to the necessary turbine modifications when using a particular self-hoisting crane technology.
- Clarity is required on the business strategy for SHC utilisation in the O&M strategy. It is unknown if self-hoisting cranes will be sold or rented through contracts and how this could affect the commercial O&M strategies of wind farm operators. This would enable much of the industry to develop their required investment roadmaps.

ABOUT THE FLOATING WIND JIP

The Floating Wind Joint Industry Project (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
- Industrialisation
- De-risking technology challenges
- Identifying innovative solutions
- Cost reduction

This Fabrication, Infrastructure and Logistics (FIL) study was delivered under Stage 2 Phase V of the floating wind JIP. Contrasting to previous phases, the Floating Wind JIP partners decided to publish individual project reports for Phase V due to an increased number of projects with different durations. The summary reports for previous Stage 2 phases can be found here: Phase I, Phase II, Phase III and Phase IV.

Stage 1 (2016-17)
Feasibility of floating offshore wind

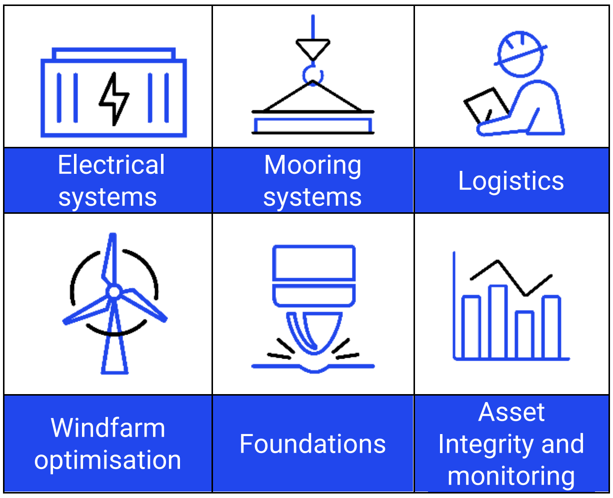
3 projects
5 project partners

Stage 2 (2017-22)
Technical challenges of floating offshore wind

35 projects
2 technology competitions
17 project partners

Stage 3 (2022-26)
Technology development for large-scale deployment of floating offshore wind

8 projects in Phase 1
More opportunities to come



Research areas

The Floating Wind JIP identified six research areas where further understanding and advancement is required to reach full commercialisation of floating offshore wind projects.

These research areas are explored through different Carbon Trust research mechanisms such as common R&D projects, Discretionary Projects and Industry Competitions.

ABOUT THE CARBON TRUST

Who we are

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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