I3FLOAT Floating Wind Strategic Innovation Agenda

Preliminary definition of Innovation lines for the prioritisation process

Design and construction

1 Floating substructures, mooring systems and dynamic cables
- 1.1 Design and engineering of floating substructures (floaters)
- 1.2 Mooring and anchoring design
- 1.3 Dynamic submarine cable systems for floating offshore wind

2 Electrical infrastructure and grid connection
- 2.1 Floating substations and electrical conversion
- 2.2 Grid management and stability for floating wind farms

3 Wind turbine, tower or alternative supporting structures and FOW-specific control
- 3.1 Adaptation of the wind turbine (WTG) and tower to floating foundation
- 3.2 Control and dynamic behaviour of the floating system
- 3.3 Validation and aero-hydro-servo modelling for FOW

4 Wind farm layout design and site planning
- 4.1 Site characterisation and wind farm planning
- 4.2 Integrated wind farm design (co-design)
- 4.3 Environmental impact and ecosystem effect mitigation

Industrialisation, logistics and offshore installation

5 Industrialisation
- 5.1 Modularisation, process-oriented standardisation and industrial automation
- 5.2 Port-based component integration and heavy lifting operations

6 Logistics and offshore installation
- 6.1 Logistics, load-out, float-off, wet storage and port-to-site transport
- 6.2 Offshore installation and hook-up of platforms, cables and mooring systems

O&M and Decommissioning

7 Operation & Maintenance and Decommissioning
- 7.1 Data acquisition for O&M digitalisation
- 7.2 Data management and structuring for O&M digitalisation
- 7.3 Data exploitation for O&M digitalisation
- 7.4 Heavy offshore maintenance and major offshore interventions
- 7.5 Decommissioning, repowering and end-of-life strategies of the floating system

Co-funded by the European Union

Area 1 - Floating substructures, mooring systems and dynamic cables

Innovation Line
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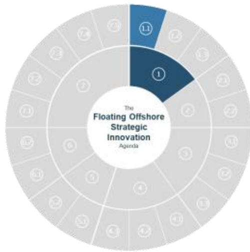

Lifecycle Stage: Design and construction

Area 1: Floating substructures, mooring systems and dynamic cables

Subarea 1.1: Design and engineering of floating substructures (floaters)

1.1.1 Multi-criteria hydrodynamic optimisation of floating substructures

Development and application of multi-criteria hydrodynamic optimisation methods for floating substructures, aiming to reduce structural loads and improve global dynamic response (e.g. motion amplitudes, acceleration levels and energy capture) under a wide range of meteorological and oceanographic conditions, while accounting for coupled floater–mooring–control interactions.

Technological Objective

To improve floating substructure performance by optimising hull geometry and hydrodynamic behaviour, balancing multiple design criteria such as motions, loads, stability, structural response and response to waves, while accounting for site-specific metocean conditions and key system-level interactions.

Specific Actions

- Application and refinement of existing multi-criteria hydrodynamic optimisation approaches to floating substructure design, considering motions, loads, stability and cost-related drivers
- Integration of hydrodynamic optimisation workflows into early-stage and FEED-level floating wind design processes
- Assessment of coupled floater-mooring-control interactions and their influence on hydrodynamic optimisation outcomes
- Evaluation of reduced-order, surrogate and uncertainty-aware optimisation approaches for accelerated design-space exploration
- Validation using scaled physical model tests where appropriate, to confirm numerical predictions and optimisation outcomes under representative conditions

Validation and Trial Needs

- Verification of optimised designs through high-fidelity numerical hydrodynamic simulations against defined performance metrics (e.g. motion response, load reduction, fatigue behaviour and stability criteria)
- Comparison of optimised and baseline substructure designs to quantify performance improvements based on defined optimisation criteria and key performance indicators
- Assessment of global dynamic behaviour, including natural frequencies and representative coupled loading conditions, under operational and extreme metocean scenarios
- Validation using scaled physical model tests where appropriate

Expected Results

- Reduced hydrodynamic loads acting on floating substructures
- Improved global response and dynamic robustness of floating platforms under varying metocean conditions
- More robust and efficient hull designs supporting downstream structural and system-level optimisation

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Innovation Line
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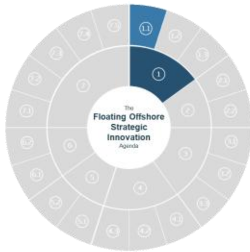

Lifecycle Stage: Design and construction

Area 1: Floating substructures, mooring systems and dynamic cables

Subarea 1.1: Design and engineering of floating substructures (floaters)

1.1.2 Coupled aero-hydro-servo modelling under representative metocean conditions

Development and application of fully coupled aero-hydro-servo-elastic numerical models for floating wind systems, enabling end-to-end system-level modelling by integrating rotor aerodynamics, floating substructure hydrodynamics and structural response, mooring system dynamics and control systems under representative and extreme metocean conditions.

Technological Objective

To improve the accuracy and reliability of system-level simulations for floating wind systems, enabling robust prediction of coupled aerodynamic, hydrodynamic, structural and mooring responses to support design optimisation, control strategies and risk reduction.

Specific Actions

- Enhancement of coupled aero-hydro-servo-elastic modelling frameworks for floating systems
- Improved representation of non-linear hydrodynamic effects, aerodynamic-control interactions, structural flexibility and mooring dynamics
- Definition of representative metocean load cases for floating wind applications, including extreme and combined loading conditions
- Benchmarking and harmonisation of modelling approaches and assumptions
- Assessment of surrogate and reduced-order modelling approaches to support accelerated simulation and design workflows

Validation and Trial Needs

- Verification against scaled physical model tests and available full-scale monitoring data, including the definition of benchmark cases and cross-validation against existing numerical tools and tank test results
- Cross-comparison of numerical tools using agreed reference cases to assess consistency and reliability of results, as well as sensitivity and uncertainty analyses to assess model robustness
- Assessment of model performance under representative extreme and coupled metocean loading scenarios

Expected Results

- Increased confidence in system-level design loads, dynamic behaviour and performance predictions for floating wind systems
- Reduced design conservatism and uncertainty margins
- Improved basis for control system development and integrated design decisions

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Innovation Line
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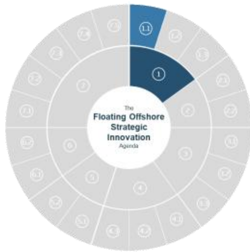

Lifecycle Stage: Design and construction

Area 1: Floating substructures, mooring systems and dynamic cables

Subarea 1.1: Design and engineering of floating substructures (floaters)

1.1.3 Substructure design geared towards O&M and major component replacement

Design of floating substructures incorporating O&M-driven criteria to directly reduce operational costs, inspection requirements and major component replacement complexity, enabling safe access, inspection, maintenance and replacement of major wind turbine components through optimised geometry, layout and integration with support and lifting systems.

Technological Objective

To reduce operational downtime, inspection requirements, logistical complexity and life-cycle costs by integrating O&M and major component replacement requirements into the early design of floating substructures.

Specific Actions

- Definition of design criteria for accessibility, manoeuvrability and safe working conditions on floating substructures
- Integration of concepts for major component replacement (for example, blades, nacelle, drivetrain) in floating configurations
- Assessment of interfaces with vessels, lifting solutions and port-based or offshore strategies
- Evaluation of O&M-driven design trade-offs at system level
- Assessment of ballast system lifecycle considerations, including corrosion management, inspection accessibility, ballast operations and implications for maintenance, repair and decommissioning activities

Validation and Trial Needs

- Simulation of O&M and major component replacement scenarios under representative offshore conditions, including case studies and associated success metrics (e.g. reduction in replacement time, cost and downtime)
- Validation through pilot projects, demonstrators or operational experience, including the assessment of defined performance and success metrics
- Numerical assessment of ballast system behaviour, corrosion mitigation approaches and operational constraints during representative lifecycle phases
- Assessment of safety, feasibility and operational limits

Expected Results

- Reduced O&M costs and downtime for floating wind turbines
- Increased feasibility of major component replacement strategies offshore or nearshore
- Improved operational safety and lifecycle performance

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Innovation Line
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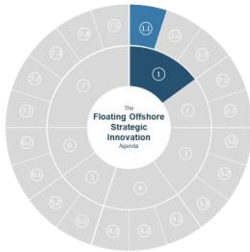

Lifecycle Stage: Design and construction

Area 1: Floating substructures, mooring systems and dynamic cables

Subarea 1.1: Design and engineering of floating substructures (floaters)

1.1.4 Specific multirotor design

Development and assessment of floating substructure process design approaches tailored to multirotor wind turbine concepts, supporting a promising pathway to reduce cost per MW by optimising load distribution, global stability and integration constraints associated with multiple rotors on a single floating platform.

Technological Objective

To enable technically feasible and scalable floating multirotor solutions through dedicated substructure design approaches that account for the specific aerodynamic, structural and operational characteristics of multirotor configurations.

Specific Actions

- Definition of substructure design requirements for multirotor floating systems
- Development of design methodologies and tools adapted to multirotor concepts
- Analysis of load paths, structural interactions and dynamic coupling between multiple rotors and the floating platform
- Development of hybrid numerical-experimental approaches for modelling aerodynamic forces during wave-basin testing of multirotor floating wind systems
- Assessment of manufacturability, transport, installation and O&M implications of multirotor substructures

Validation and Trial Needs

- Validation of multirotor-specific substructure design approaches through advanced numerical modelling (e.g. multibody simulation) and comparative studies against single-rotor reference configurations
- Assessment of global load paths, stability margins and dynamic behaviour under representative floating wind conditions, supported by wind-tunnel and/or wave-basin testing of representative multi-turbine models

Expected Results

- Improved understanding of multirotor-specific substructure behaviour
- Design methodologies enabling reliable and optimised multirotor floating platforms
- Reduced technical uncertainty for future multirotor floating wind developments

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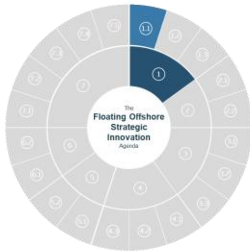

Lifecycle Stage: Design and construction

Area 1: Floating substructures, mooring systems and dynamic cables

Subarea 1.1: Design and engineering of floating substructures (floaters)

1.1.5 Standardisation and modularisation of floating substructures

Development of standardised and modular design frameworks for floating substructures, aligned with industry trends towards modularisation for large-scale deployment, based on repeatable structural modules and common interfaces, enabling industrial series production through consistent fabrication, assembly and integration processes across floating wind projects.

Technological Objective

To enable industrial-scale deployment of floating wind substructures by reducing design variability and engineering effort through modular construction approaches, while allowing controlled adaptation to different turbine configurations, site conditions, water depths and structural requirements without compromising fabrication and assembly efficiency.

Specific Actions

- Identification and definition of common structural and functional interfaces between substructure modules, turbine tower, mooring systems and auxiliary equipment
- Development of modular substructure architectures allowing configuration flexibility without full redesign
- Assessment of load transfer, tolerances and structural continuity at modular interfaces
- Evaluation of repeatable industrial processes for modular fabrication, assembly, transport and integration

Validation and Trial Needs

- Numerical verification of structural, hydrodynamic and dynamic performance of modular configurations
- Prototype manufacturing and assembly of representative modules to validate interfaces, tolerances, compliance with standardisation requirements and construction sequences
- Demonstration of modular integration at pilot or pre-commercial project scale, including verification of standardised interfaces and assembly tolerances under realistic conditions

Expected Results

- Increased use of repeatable structural modules and common interfaces across floating substructure designs
- Improved scalability, consistency and efficiency of fabrication, assembly and integration processes for floating wind substructures
- Reduction of project-specific engineering effort and industrial complexity, supporting progressive industrialisation of floating wind

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Innovation Line
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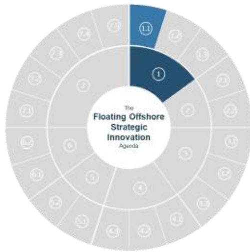

Lifecycle Stage: Design and construction

Area 1: Floating substructures, mooring systems and dynamic cables

Subarea 1.1: Design and engineering of floating substructures (floaters)

1.1.6 Concrete construction solutions for floating substructures

Development and optimisation of industrialised construction processes for concrete floating substructures, leveraging the structural, durability and cost advantages of concrete in marine environments. The line includes advanced concrete mix designs, reinforcement solutions and industrial construction techniques, such as sliding and climbing formwork, to improve structural performance, durability, production scalability and cost-efficiency.

Technological Objective

To enable scalable and cost-effective deployment of concrete floating substructures by advancing industrial construction methods, concrete mix optimisation and reinforcement solutions that ensure structural quality, dimensional accuracy and long-term durability in offshore environments.

Specific Actions

- Adaptation of sliding and climbing formwork techniques to floating substructure geometries and construction sequences
- Development and optimisation of concrete mix designs, reinforcement solutions and construction materials suitable for offshore exposure, long-term durability and industrialised production
- Assessment of construction tolerances, quality control, repeatability and cost-efficiency in industrialised concrete fabrication processes
- Evaluation of interfaces between concrete substructures and steel components, mooring systems and towers
- Evaluation of pumping, placing and curing methodologies for large-scale concrete floating structures under representative industrial conditions

Validation and Trial Needs

- Prototype construction of representative concrete substructure elements using industrialised processes
- Validation of pumping, placing and curing procedures through representative industrial-scale trials
- Structural, durability and fatigue testing under representative environmental conditions, including accelerated ageing tests for concrete mixes and materials
- Monitoring of pilot or demonstration projects to validate construction quality, structural performance and long-term durability

Expected Results

- Reduced construction costs and improved scalability of concrete floating substructures
- Enhanced durability, reduced maintenance requirements and improved lifecycle cost-efficiency
- Increased industrial maturity and manufacturability of concrete-based floating solutions

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Innovation Line
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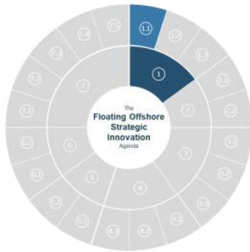

Lifecycle Stage: Design and construction

Area 1: Floating substructures, mooring systems and dynamic cables

Subarea 1.1: Design and engineering of floating substructures (floaters)

1.1.7 Design of adaptable floating substructures compatible with multiple wind turbine tower configurations

Development of floating substructures with adaptable tower-floater interfaces to accommodate multiple wind turbine tower configurations within a defined geometry and load envelope. The line targets platform reuse across turbine suppliers and upscaling scenarios, reducing redesign effort while maintaining industrial manufacturability and integration readiness.

Technological Objective

To enable reuse of a standard floater platform across multiple wind turbine configurations by standardising the tower-floater interface and defining the compatibility envelope in terms of turbine ratings, tower geometries, load sets and integration constraints, while ensuring stability, motions and structural margins under representative metocean conditions.

Specific Actions

- Definition of system compatibility envelope (geometry, loads, tolerances and design limits) for target turbine configurations, including tower, RNA and relevant interface constraints
- Development of modular interface / transition components and standardised load-transfer details (adapters, joints and bolted/flanged concepts), considering integration constraints related to tower access and internal equipment arrangement
- Integration of coupled aero-hydro-servo-elastic and structural checks into concept and FEED workflows to derive design rules across representative configuration ranges

Validation and Trial Needs

- Verification through high-fidelity coupled simulations (ULS/FLS) across representative tower variants and site conditions, with particular focus on worst-case load combinations
- Detailed verification of interface integrity (local stresses, joints, fatigue hot-spots), accounting for tolerance and assembly sensitivity while ensuring structural margins across all configuration variations
- Prototype or scaled trials focused on interface behaviour, supported by pilot integration testing and assessment of manufacturability and installation sequence feasibility

Expected Results

- Adaptable tower-floater interface enabling turbine interchangeability within a defined envelope
- Reduced redesign and FEED rework when turbine/tower selection changes, shortening integration lead time
- Increased platform standardisation supporting serial manufacturing and repeatable integration/installation

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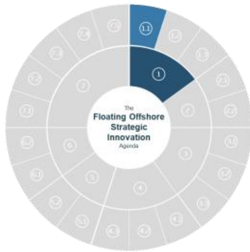

Lifecycle Stage: Design and construction

Area 1: Floating substructures, mooring systems and dynamic cables

Subarea 1.1: Design and engineering of floating substructures (floaters)

1.1.8 Component reliability, structural health monitoring and digital twins for floating substructures

Development and integration of reliability and structural health monitoring (SHM) solutions for floating substructures, combining sensor systems, data acquisition/management and hybrid (physics + data-driven) models to enable digital twins. The line targets early detection of degradation, improved integrity management and condition-based maintenance through actionable KPIs (fatigue, corrosion, joint integrity, motions/loads) and decision support for inspection and operations, with particular attention to ballast tanks, welded joints and other fatigue- and corrosion-sensitive areas.

Technological Objective

To increase floater availability and lifetime by deploying integrated SHM + digital twin solutions that quantify structural condition, predict degradation and support risk-based inspection and maintenance under real operating conditions.

Specific Actions

- Perform degradation and failure mode analysis for critical floating substructure components and systems, identifying fatigue- and corrosion-sensitive areas to support SHM architecture definition
- Develop integrated SHM architectures (sensors, DAQ, telemetry and edge processing) tailored to critical floater components and degradation hotspots, including ballast tanks and welded connections, while addressing data integration, interoperability and system scalability challenges
- Build hybrid digital twin models linking measured responses to loads, fatigue damage and remaining useful life (RUL) estimates
- Define reliability KPIs, alert thresholds and decision workflows (inspection planning, repair triggers) compatible with O&M systems and risk-based integrity management approaches

Validation and Trial Needs

- Lab and component-level validation of sensors and mounting solutions (durability, drift, marine environment, calibration)
- Offshore pilot deployment on representative operating floaters to validate anomaly detection, KPI accuracy and model updating across defined monitoring systems
- Demonstration of end-to-end integration (data pipeline, cybersecurity, SCADA/O&M interfaces) and performance benchmarking against baseline O&M practices

Expected Results

- Earlier detection of degradation and reduced unplanned interventions through condition-based maintenance
- Improved structural integrity management with quantified fatigue/corrosion evolution and RUL prediction
- Reduced inspection cost and downtime via risk-based inspection planning and digital evidence for decision-making

Current TRL

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Innovation Line
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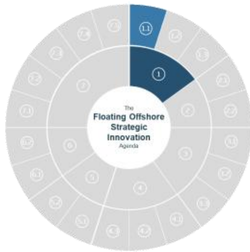

Lifecycle Stage: Design and construction

Area 1: Floating substructures, mooring systems and dynamic cables

Subarea 1.1: Design and engineering of floating substructures (floaters)

1.1.9 Biofouling-aware design of floating substructures

Integration of marine biofouling effects into the structural and hydrodynamic design of floating substructures to ensure long-term performance, integrity and operability. The line addresses the influence of biofouling growth on added mass and drag, motions and loads, corrosion protection systems, inspection accessibility and long-term weight distribution, enabling the development of design allowances and mitigation strategies compatible with industrial deployment while considering environmental constraints and potential risks associated with invasive aquatic species.

Technological Objective

To ensure long-term floater performance and integrity by incorporating biofouling growth, location and evolution into design loads, accounting for uncertainties in biological processes (e.g. growth rates and distribution), integrating these effects into hydrodynamic response and maintenance strategies, and considering mitigation approaches to reduce operational, integrity and invasive aquatic species risks over the asset lifetime.

Specific Actions

- Define biofouling scenarios and design allowances by zone (splash / intertidal / submerged), including growth rates, roughness evolution and potential invasive aquatic species considerations for target sites
- Integrate biofouling-induced hydrodynamic penalties (drag, added mass, damping) into coupled analyses and design load case selection
- Develop design and mitigation solutions (coatings, surface treatments, geometry details and inspection access provisions) compatible with long-term inspection and maintenance

Validation and Trial Needs

- Validation of biofouling models and parameters using field data and monitoring campaigns in representative environments, in collaboration with marine biology experts to ensure realistic fouling assumptions
- Numerical verification of performance sensitivity (motions, loads, fatigue) with and without biofouling allowances across key metocean conditions
- Demonstration of mitigation effectiveness and long-term maintainability through pilot trials and field exposure testing, including inspection accessibility and cleanability assessment

Expected Results

- Design rules and validated allowances for biofouling impacts on hydrodynamics, loads and weight growth
- Improved long-term platform performance stability (motions, station-keeping margins, operability) and reduced uncertainty in design
- Reduced O&M burden and integrity risks through optimised mitigation, inspection and cleaning strategies compatible with long-term offshore operation and environmental constraints

Current TRL

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Innovation Line
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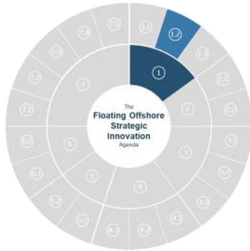

Lifecycle Stage: Design and construction

Area 1: Floating substructures, mooring systems and dynamic cables

Subarea 1.2: Mooring and anchoring design

1.2.1 Qualification, certification and application of advanced synthetic materials for taut mooring systems

Qualification and application of advanced synthetic materials for floating wind taut mooring systems, focusing on testing, characterisation and operational use of high-performance synthetic ropes to enable taut mooring configurations, reduce system weight, improve fatigue performance and support reliable deployment in deep-water applications.

Technological Objective

To enable reliable and widespread use of synthetic materials in floating wind taut mooring systems by developing qualification and certification approaches, improving long-term performance and ensuring integration under representative offshore conditions.

Specific Actions

- Mechanical and fatigue characterisation of advanced synthetic materials under cyclic and long-term loading, including accelerated testing methodologies and representative floating wind load spectra for lifetime prediction
- Assessment of creep, ageing (including UV exposure), abrasion, hysteresis and environmental degradation effects under offshore conditions, with focus on long-term performance and rope damping behaviour
- Development of qualification and certification methodologies and design guidelines for synthetic mooring systems, including rope protection and jacketing approaches
- Evaluation of handling, installation and inspection requirements compared to conventional steel solutions
- Assessment of interfaces between synthetic ropes, connectors, terminations and steel segments under representative operational loading conditions
- Development of load emulation methodologies for synthetic taut mooring systems in basin testing environments representative of coupled floating wind turbine behaviour

Validation and Trial Needs

- Laboratory testing at material and subcomponent level, including fatigue, durability and accelerated ageing tests using representative tension cycles and load amplitudes
- Full-scale, representative segment or basin-scale testing under realistic coupled load spectra and offshore operational conditions
- Monitoring of pilot or demonstration projects to validate construction quality and performance
- Long-term in-service monitoring to validate degradation behaviour, fatigue performance, inspection strategies and long-term operational reliability

Expected Results

- Reduced mooring system weight and improved dynamic response of floating wind platforms
- Enhanced fatigue life, damping behaviour and reliability of synthetic mooring systems
- Increased confidence and acceptance of synthetic materials in floating wind mooring design

Current TRL

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Innovation Line
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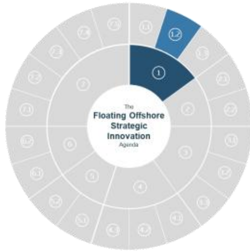

Lifecycle Stage: Design and construction

Area 1: Floating substructures, mooring systems and dynamic cables

Subarea 1.2: Mooring and anchoring design

1.2.2 Single Point Mooring (SPM) design

Adaptation and application of established Single Point Mooring (SPM) design criteria and analysis tools to floating wind platforms, addressing station-keeping performance, load distribution, fatigue behaviour, operational reliability and turbine-platform interaction under floating wind operating conditions, with a focus on simplified mooring configurations that reduce system complexity and overall costs

Technological Objective

To enable safe, reliable and cost-effective application of SPM concepts in floating wind by adapting established offshore mooring approaches to the dynamic, operational and lifecycle requirements of wind turbine platforms, including turbine-platform interaction effects.

Specific Actions

- Definition of SPM-specific design requirements for floating wind applications
- Assessment of load distribution, redundancy and failure modes in SPM configurations
- Development and adaptation of numerical tools for coupled analysis of SPM systems, floating wind platforms and turbine-platform interaction effects
- Evaluation of fatigue behaviour of key SPM components under cyclic wind and wave loading
- Assessment of redundancy, failure consequences and emergency disconnection strategies in SPM configurations

Validation and Trial Needs

- Numerical validation using representative floating wind SPM reference cases
- Physical model testing to assess global behaviour and load paths
- Monitoring of pilot or demonstration projects to validate operational performance and reliability
- Validation of SPM behaviour under extreme, transient and abnormal operational conditions

Expected Results

- Validated design criteria and analysis tools for SPM systems in floating wind
- Improved understanding of benefits and limitations of SPM concepts compared to multi-line mooring systems
- Enhanced confidence in operational reliability and station-keeping performance

Current TRL

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Innovation Line
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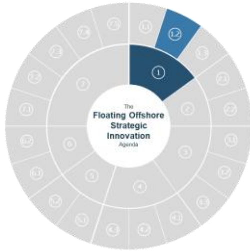

Lifecycle Stage: Design and construction

Area 1: Floating substructures, mooring systems and dynamic cables

Subarea 1.2: Mooring and anchoring design

1.2.3 Probabilistic fatigue and failure models for mooring and anchoring systems

Development of probabilistic models to assess fatigue damage accumulation and failure likelihood in floating wind mooring and anchoring systems, explicitly accounting for uncertainties in loads, material properties, coupled floater-mooring-cable dynamics, degradation mechanisms and operational conditions. The line addresses time-varying degradation effects and monitoring-informed approaches to improve reliability, safety and robustness in system design and operation.

Technological Objective

To support risk-informed design and operational decisions for floating wind mooring and anchoring systems by moving from deterministic safety factors to probabilistic assessment of fatigue life and failure probability, including integration with monitoring systems and operational data to support continuous model updating and decision-making

Specific Actions

- Application of probabilistic fatigue and reliability modelling approaches to floating wind mooring and anchoring systems under representative operational conditions
- Development of uncertainty quantification frameworks covering metocean variability, modelling assumptions, material properties and degradation mechanisms relevant to floating wind applications
- Integration of monitoring and operational data (e.g. strain, tension and inspection measurements) into probabilistic fatigue models and risk-informed assessment methodologies
- Investigation of coupled floater-mooring-dynamic cable interactions and their implications for fatigue accumulation, degradation evolution and failure probability
- Investigation of degradation mechanisms affecting mooring materials and components, including corrosion, wear, creep, abrasion, ageing and biofouling

Validation and Trial Needs

- Calibration of probabilistic models using laboratory fatigue data, field measurements and long-term monitoring datasets representative of floating wind operational conditions
- Validation under both fatigue and extreme load conditions, including transient and rare environmental events relevant to floating wind systems
- Cross-validation between different modelling approaches and datasets to assess robustness, uncertainty sensitivity and industrial applicability
- Comparison between predicted degradation trends, monitored fatigue accumulation and observed failure cases where operational data are available
- Application to representative floating wind mooring and anchoring configurations through pilot or pre-commercial projects where possible

Expected Results

- Improved prediction accuracy and quantified probability of fatigue failure for floating wind mooring and anchoring systems
- Reduced uncertainty and design conservatism in mooring system assessment and lifetime prediction
- Improved basis for risk-informed design, inspection and maintenance interval optimisation strategies
- Increased reliability, transparency and confidence in mooring system performance under representative floating wind operating conditions

Current TRL

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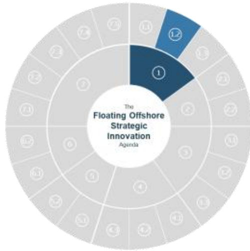

Lifecycle Stage: Design and construction

Area 1: Floating substructures, mooring systems and dynamic cables

Subarea 1.2: Mooring and anchoring design

1.2.4 Multi-segment and multi-material designs for mooring lines

Development and optimisation of mooring line architectures combining multiple segments and materials (for example, steel chains, qualified synthetic ropes and hybrid configurations), focusing on system-level design of hybrid mooring lines to optimise stiffness distribution, load sharing, fatigue performance and installation efficiency in floating wind applications.

Technological Objective

To enable efficient and reliable hybrid mooring line configurations for floating wind by optimising the arrangement, length and material selection of individual segments, while accounting for multidisciplinary impacts on platform dynamics, structural response, inter-array cable feasibility and wind turbine performance under site-specific conditions.

Specific Actions

- Definition of representative multi-segment and multi-material mooring line configurations for floating wind systems
- Assessment of global and local load distribution, stiffness variation and dynamic response along hybrid mooring lines
- Evaluation of fatigue behaviour and degradation mechanisms at material transition zones and connectors
- Development of design guidelines for the selection, dimensioning and arrangement of mooring line segments at system level

Validation and Trial Needs

- Numerical modelling of representative hybrid mooring line configurations under realistic operational and extreme load conditions
- Testing of critical interfaces and transition zones between different materials and segments
- Validation through application in pilot or demonstration floating wind projects

Expected Results

- Optimised hybrid mooring line designs with improved fatigue performance and reduced system weight
- Increased flexibility to tailor mooring systems to different site conditions and water depths without full redesign
- Reduced material usage and overall mooring system costs through system-level optimisation

Current TRL

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Current TRL	☐	☐	☐	■	☐

Innovation Line
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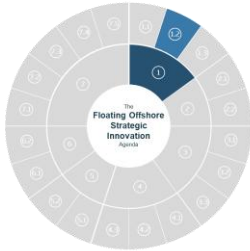

Lifecycle Stage: Design and construction

Area 1: Floating substructures, mooring systems and dynamic cables

Subarea 1.2: Mooring and anchoring design

1.2.5 Innovations in low environmental impact anchoring systems and shared mooring architectures

Development and assessment of anchoring and mooring solutions for floating wind aimed at minimising seabed disturbance and overall environmental footprint under variable marine conditions, including innovative low-impact anchor concepts and shared mooring configurations enabling multiple floating units to connect to common anchoring systems while considering lifecycle, reuse and decommissioning aspects.

Technological Objective

To reduce the environmental and spatial footprint of anchoring systems while ensuring structural integrity, operational safety and system reliability, through the development of low-impact anchor solutions and shared mooring configurations adapted to varying seabed conditions and optimised for efficient installation, material use and lifecycle performance at wind farm scale.

Specific Actions

- Development and assessment of low-impact anchor concepts suitable for different seabed conditions and environmental constraints
- Evaluation of installation, removal, decommissioning, reuse and life-extension strategies with reduced seabed disturbance
- Analysis and development of shared mooring architectures, including load sharing, network topology, redundancy and failure scenarios for multi-turbine configurations
- Assessment of environmental, operational and regulatory implications of low-impact and shared anchoring solutions, including ecological and lifecycle footprint considerations

Validation and Trial Needs

- Numerical and physical testing of innovative anchoring concepts under representative load conditions
- Pilot-scale installation and monitoring to assess seabed interaction, environmental impact and operational performance
- Validation of shared anchoring concepts through representative case studies and demonstrators, including redundancy and failure response assessment

Expected Results

- Reduced environmental footprint of anchoring solutions through optimised design, installation and reuse strategies
- Improved compatibility of anchoring and mooring systems with seabed conditions, regulatory requirements and long-term operational constraints
- Improved feasibility and reliability of shared anchoring concepts to reduce seabed occupation and overall infrastructure footprint in floating wind farms

Current TRL

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Current TRL	■	□	□	□	□

Innovation Line
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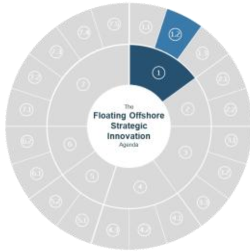

Lifecycle Stage: Design and construction

Area 1: Floating substructures, mooring systems and dynamic cables

Subarea 1.2: Mooring and anchoring design

1.2.6 Mooring connectors and hook-up systems

Development and optimisation of connectors and hook-up systems for floating wind mooring lines, focusing on solutions that simplify, accelerate and increase the safety of mooring line connection and disconnection during offshore installation, inspection, maintenance and decommissioning or retrieval operations, while minimising offshore personnel intervention and reducing operational time.

Technological Objective

To reduce installation time, offshore operation complexity and safety risks by enabling reliable, efficient and repeatable mooring connection and hook-up solutions adapted to floating wind operational and lifecycle requirements.

Specific Actions

- Development of connector concepts suitable for offshore installation with limited vessel capability, including the definition of key design criteria (e.g. blind-mate hydraulic systems) and compatibility with high mooring line tensions representative of commercial floating wind applications
- Design of hook-up procedures compatible with floating platform motions and operational constraints
- Assessment of mechanical performance, fatigue behaviour and durability of connectors under cyclic loading
- Evaluation of inspection, replacement and disconnection strategies for connectors during operation, maintenance and decommissioning phases, prioritising diverless and reduced-personnel offshore operations
- Validation of connector prototypes through diver- and ROV-assisted dry runs under representative offshore conditions

Validation and Trial Needs

- Mechanical and fatigue testing of connectors at component level
- Offshore trials or pilot-scale demonstrations of hook-up and unhooking procedures
- Validation of installation time, safety and operability under representative sea states

Expected Results

- Faster and safer mooring installation and connection operations
- Reduced dependence on highly specialised vessels and weather windows
- Improved reliability and maintainability of mooring systems over the lifecycle

Current TRL

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Innovation Line
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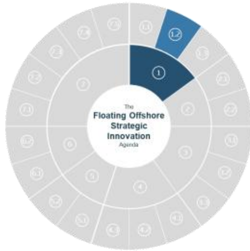

Lifecycle Stage: Design and construction

Area 1: Floating substructures, mooring systems and dynamic cables

Subarea 1.2: Mooring and anchoring design

1.2.7 Load Reduction Devices for mooring systems

Development and integration of active or passive load management solutions for mooring systems, aimed at mitigating extreme and fatigue loads and improving overall system durability and performance.

Technological Objective

To reduce peak and cyclic loads in mooring systems through active tension management, thereby improving fatigue life, operational reliability and overall system performance without oversizing mooring components.

Specific Actions

- Identification of the main mooring load drivers that can be influenced through active or semi-active control strategies
- Development of active, passive or semi-active load reduction device concepts (e.g. hydraulic tension management, damping and energy dissipation systems) compatible with floating wind mooring configurations
- Integration of control algorithms linking environmental conditions, platform response and mooring tension
- Assessment of system-level impacts, including reliability, redundancy, robustness and failure consequences

Validation and Trial Needs

- Numerical simulation and scaled experimental validation of controlled mooring systems under operational and extreme load scenarios
- Hardware-in-the-loop or component-level testing of load reduction devices and control strategies
- Demonstration of load reduction performance, component reliability and system robustness through pilot integration on a single mooring line, including real-time load monitoring under representative sea conditions

Expected Results

- Reduced extreme loads and fatigue damage in mooring lines
- Extended mooring system service life and reduced inspection and replacement needs
- Increased design flexibility and potential reduction of mooring system oversizing

Current TRL

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Current TRL					

Innovation Line
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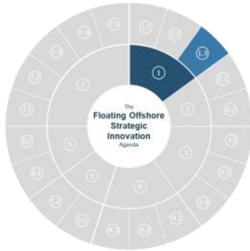

Lifecycle Stage: Design and construction

Area 1: Floating substructures, mooring systems and dynamic cables

Subarea 1.3: Dynamic submarine cable systems for floating offshore wind

1.3.1 Qualification and standardisation of dynamic cables

Qualification and standardisation of dynamic submarine cable solutions for floating wind applications through coordinated testing and assessment programmes, building on existing dynamic cable designs to support reliable deployment and industrialisation.

Technological Objective

To increase confidence, reliability and industrial readiness of dynamic cables for floating wind by establishing consistent qualification methodologies and standard testing frameworks applicable across projects and cable configurations.

Specific Actions

- Definition of representative load cases and test conditions for dynamic cables in floating wind applications
- Development of combined testing programmes addressing mechanical, electrical and environmental performance simultaneously
- Assessment of fatigue behaviour, degradation mechanisms and failure modes under coupled loading conditions
- Alignment of qualification approaches with certification bodies and industry standards

Validation and Trial Needs

- Execution of laboratory testing campaigns using representative dynamic cable sections and test setups
- Comparison of test results across different cable designs and manufacturers to assess repeatability
- Validation of qualification methodologies through application in pilot or demonstration floating wind projects

Expected Results

- Improved reliability and predictability of dynamic cable performance
- Reduced project-specific qualification effort and testing duplication
- Increased standardisation and acceptance of dynamic cable solutions across the floating wind sector

Current TRL

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Innovation Line
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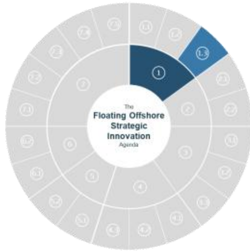

Lifecycle Stage: Design and construction

Area 1: Floating substructures, mooring systems and dynamic cables

Subarea 1.3: Dynamic submarine cable systems for floating offshore wind

1.3.2 Development of quick-connect and disconnect connectors

Development and adaptation of quick-connect and disconnect connector solutions for dynamic submarine power cables in floating wind, enabling efficient, safe and repeatable connection and disconnection during installation, commissioning and maintenance operations. These solutions aim to reduce offshore intervention time, dependence on specialised cable installation vessels and operational downtime by enabling simplified installation, tow-to-port maintenance strategies and faster replacement of damaged dynamic cables, while incorporating smart functionalities for monitoring and connection status verification.

Technological Objective

To reduce offshore installation complexity, intervention time and operational risks associated with dynamic cable connection by enabling reliable connector systems capable of withstanding mechanical and environmental loads during connection, disconnection and operation, while supporting diver-less installation strategies, simplified cable replacement operations and reduced dependence on specialised installation vessels.

Specific Actions

- Development of connector concepts suitable for dynamic cable applications under cyclic mechanical and environmental loading, including smart functionalities for alignment assistance, condition monitoring and connection verification
- Definition of installation and disconnection procedures compatible with floating platform motions, offshore constraints and diver-less operations
- Assessment of connector integrity, sealing performance and operational reliability under representative offshore conditions
- Evaluation of compatibility with existing dynamic cable designs, maintenance strategies and qualification frameworks
- Assessment of connector-enabled logistics and replacement strategies supporting tow-to-port operations and faster cable replacement

Validation and Trial Needs

- Validation of connector concepts through laboratory and controlled offshore testing under representative mechanical and environmental conditions, including assessment of alignment tolerances and pull-in loads where relevant
- Demonstration of installation and disconnection procedures through pilot-scale or representative floating wind scenarios, including ROV-assisted and diver-less operations where applicable
- Verification of operational reliability, sealing integrity and maintenance performance under representative offshore conditions

Expected Results

- Reduced offshore installation and intervention time for dynamic cables
- Improved flexibility and cost-effectiveness of installation, commissioning and maintenance operations, including tow-to-port and cable replacement strategies
- Reduced dependence on specialised cable installation vessels and enhanced operational safety through diver-less connection approaches
- Reduced risk of cable and ancillary component damage during connection and disconnection activities

Current TRL

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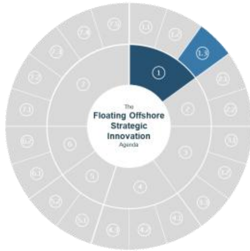

Lifecycle Stage: Design and construction

Area 1: Floating substructures, mooring systems and dynamic cables

Subarea 1.3: Dynamic submarine cable systems for floating offshore wind

1.3.3 Integrated dynamic cable curvature and shape control systems

Development and integration of coordinated cable curvature and shape control solutions for floating wind applications, combining elements such as bend stiffeners, buoyancy modules and clump weights to manage dynamic cable behaviour under representative operating conditions, including applications involving large-diameter and extra-high-voltage (EHV) cables.

Technological Objective

To ensure long-term integrity and fatigue performance of dynamic cables by actively managing cable geometry and curvature along the water column under variable environmental and operational conditions, including configurations involving large-diameter or extra-high-voltage cables.

Specific Actions

- Assessment of cable curvature drivers and critical zones along dynamic cable configurations, including implications of larger diameter and stiffness associated with extra-high-voltage cables
- Development and optimisation of integrated shape control solutions combining bend stiffeners, buoyancy elements and clump weights
- System-level design of cable configuration layouts adapted to floating platform motions and site-specific conditions

Validation and Trial Needs

- Numerical simulation of controlled mooring systems under operational and extreme load scenarios
- Demonstration of load reduction performance and system robustness in pilot or demonstration floating wind project

Expected Results

- Improved control of dynamic cable curvature and configuration, reducing local stress concentrations and fatigue drivers
- Increased reliability and robustness of dynamic cable systems across a wider range of floating wind configurations
- Reduced need for project-specific cable configuration redesign through more systematic and repeatable integration approaches

Current TRL

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Current TRL					

Innovation Line
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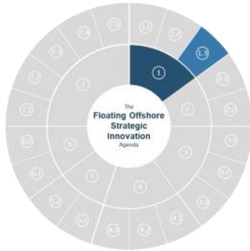

Lifecycle Stage: Design and construction

Area 1: Floating substructures, mooring systems and dynamic cables

Subarea 1.3: Dynamic submarine cable systems for floating offshore wind

1.3.4 Studies on the dynamic behaviour and environmental interactions of submarine cables

Applied assessment and integration of submarine cable dynamic behaviour and environmental interactions into cable design and project engineering. The line covers coupled fatigue/response and seabed interaction (touchdown, trenching/burial, scour, sediment mobility) together with electromagnetic field (EMF) characterisation and potential effects on marine receptors, to support design choices, routing, protection measures and permitting with reduced uncertainty.

Technological Objective

To de-risk dynamic cable design and consenting by quantifying cable-seabed-environment interactions and key dynamic response drivers (including fatigue- and vibration-related effects), and translating them into engineering design criteria, routing/protection solutions and monitoring/mitigation measures.

Specific Actions

- Develop coupled modelling workflows for dynamic response, bend stiffener and hang-off behaviour, and seabed interaction (touchdown dynamics, friction, burial / trenching, scour / sediment mobility) to predict loads and fatigue drivers
- Characterise EMF signatures for IAC/export configurations (current levels, shielding, burial depth) and link to route-specific environmental conditions and receptors
- Define design/mitigation guidelines combining routing, burial/protection, operational limits and monitoring requirements to meet performance and environmental constraints

Validation and Trial Needs

- Field data acquisition on cable motions, touchdown behaviour and seabed conditions to calibrate/validate interaction models
- Verification of EMF predictions with in-situ measurements for representative cable types, burial depths and operating regimes
- Pilot demonstration of integrated “engineering + environmental” workflow in a project case (route selection, protection design and monitoring plan)

Expected Results

- Validated design criteria and modelling methods for cable dynamics and seabed interaction, reducing fatigue and failure risk
- Quantified EMF envelopes and practical mitigation options (routing/burial/shielding) to support permitting and stakeholder acceptance
- More robust cable routing and protection strategies with reduced uncertainty, rework and environmental compliance risk

Current TRL

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Current TRL					

Innovation Line
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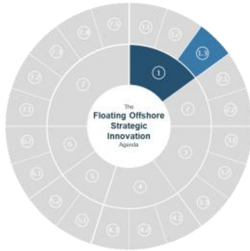

Lifecycle Stage: Design and construction

Area 1: Floating substructures, mooring systems and dynamic cables

Subarea 1.3: Dynamic submarine cable systems for floating offshore wind

1.3.5 Development of new direct current (DC) cable technologies to address the technical challenges that arise as projects move further offshore

Development of HVDC cable technologies and associated dynamic export solutions to enable floating wind projects located at longer distances from shore, where AC export becomes technically and economically limiting. The line targets cable designs, materials, accessories and dynamic sections capable of withstanding higher electrical stresses and floating-specific mechanical demands, while improving manufacturability, installation and long-term reliability.

Technological Objective

To enable reliable and cost-effective far-offshore export by developing HVDC cable systems (cables + joints/terminations + dynamic sections) that meet floating wind mechanical and electrical requirements and can be industrialised for large-scale deployment.

Specific Actions

- Develop HVDC cable designs and insulation/material systems suited to floating wind duty cycles and higher voltage levels, including thermal and electrical stress management
- Develop and qualify HVDC accessories for offshore use (joints, terminations, hang-offs, transition zones) compatible with dynamic operation and marine environment
- Define integrated design rules and installation concepts for HVDC export from floating platforms (dynamic-to-static interfaces, protection, bending management, repair strategy)

Validation and Trial Needs

- Electrical qualification testing under HVDC operating conditions (PD, ageing, thermal cycles) adapted to offshore environments
- Comparison of optimised and baseline substructure designs to quantify performance improvements
- Validation using scaled physical model tests where appropriate

Expected Results

- HVDC cable system solutions suitable for far-offshore floating wind export, including qualified accessories and dynamic interfaces
- Reduced technical risk and improved reliability for long-distance export, lowering downtime and repair exposure
- Improved industrial readiness through standardised designs, test protocols and installation procedures

Current TRL

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Innovation Line
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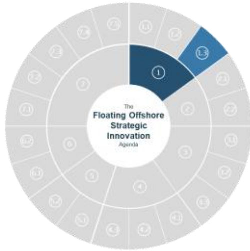

Lifecycle Stage: Design and construction

Area 1: Floating substructures, mooring systems and dynamic cables

Subarea 1.3: Dynamic submarine cable systems for floating offshore wind

1.3.6 Development of failure response and protection mechanisms for dynamic submarine cables

Development of protection and failure-response solutions for dynamic submarine cables to limit damage propagation and enable controlled disconnection/recovery in abnormal events. The line includes “fuse-type” mechanical systems, weak-link concepts and protective elements that can be integrated at defined locations and connected/handled without compromising cable integrity, aiming to reduce repair complexity, downtime and secondary failures.

Technological Objective

To improve dynamic cable system availability and safety by implementing protection mechanisms that mitigate overload events, prevent cascading damage and enable rapid, controlled intervention with minimal impact on cable integrity

Specific Actions

- Define failure modes and triggering criteria (over-tension, excessive bending, snagging, impact) and translate them into protection requirements and design limits
- Develop and engineer fuse/weak-link and protection concepts compatible with dynamic cable interfaces (hang-off, transition, I-tube) and standard installation practices
- Establish qualification methodologies and acceptance criteria for combined mechanical and operational performance, including maintainability and reset/replace procedures

Validation and Trial Needs

- Component and system-level mechanical testing (tension/bending/torsion, cyclic fatigue) to validate trigger behaviour and durability under representative load spectra
- Integration trials to confirm connection procedures, handling, and that cable electrical/mechanical integrity is not compromised by the protection device
- Demonstration in representative offshore installation/O&M scenarios (deployment, emergency disconnection, recovery and replacement workflow)

Expected Results

- Qualified fuse-type / protection solutions that limit damage propagation and protect critical cable sections
- Reduced repair time and offshore intervention complexity through controlled disconnection and recoverability
- Improved reliability and lower lifecycle risk for dynamic cable systems, increasing project bankability

Current TRL

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Current TRL					

Innovation Line
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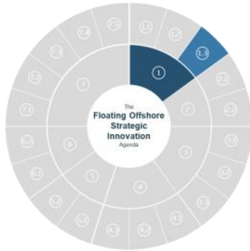

Lifecycle Stage: Design and construction

Area 1: Floating substructures, mooring systems and dynamic cables

Subarea 1.3: Dynamic submarine cable systems for floating offshore wind

1.3.7 Integrated design of dynamic cables and mooring systems

Integrated engineering of dynamic cables and mooring systems through coupled analysis and joint layout optimisation. The line addresses fully coupled floater–mooring–cable interactions, including dynamic response, installation constraints and critical interfaces (hang-offs, touchdown zones, fairleads), aiming to reduce interference and fatigue risks, improve operability and optimise allowable floater offsets under representative and extreme metocean conditions.

Technological Objective

To improve system reliability and reduce lifecycle cost by co-designing mooring systems and dynamic cables as interdependent parts of the floating wind system, optimising layouts, interfaces, installation constraints and allowable floater offsets to minimise interference risk, fatigue damage and operational limitations under representative and extreme metocean conditions.

Specific Actions

- Development of fully coupled simulation workflows capturing floater motions, mooring dynamics, cable response and control-system interactions, including interference/contact modelling and shared design load cases
- Investigation of interaction and failure propagation mechanisms between cables and mooring systems under representative operational and extreme conditions, including assessment of critical interfaces and clash-risk mitigation solutions
- Development of integrated layout optimisation methodologies considering anchor patterns, cable corridors, allowable floater offsets, installation and maintenance constraints, and seabed conditions
- Definition of integrated design rules and standard interface solutions for cable-mooring systems to improve operability, reduce fatigue hot-spots and support robust lifecycle performance

Validation and Trial Needs

- Verification through high-fidelity coupled analyses across representative floater/mooring/cable configurations, including sensitivity to offsets, installation tolerances and extreme events
- Cross-validation of numerical tools and modelling approaches using long-term monitoring data and demonstrator project information where available
- Physical model testing of combined cable–mooring configurations to validate coupled behaviour under representative operational and accidental load cases
- Demonstration through FEED-level studies and pilot or pre-commercial projects, including installation methodologies and early operational considerations

Expected Results

- Optimised cable-mooring layouts with reduced interference risk, improved allowable floater offsets and fewer operational constraints
- Improved predictability and reliability of coupled cable-mooring system behaviour under representative floating wind operating conditions
- Lower fatigue loads and improved lifetime margins at critical cable and mooring interfaces
- More robust and repeatable engineering workflows supporting faster design cycles, improved operability and reduced lifecycle risk

Current TRL

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Area 2 - Electrical infrastructure and grid connection

Innovation Line
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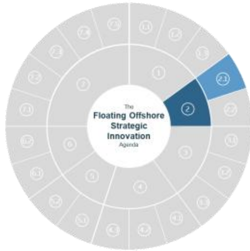

Lifecycle Stage: Design and construction

Area 2: Electrical infrastructure and grid connection

Subarea 2.1: Floating substations and electrical conversion

2.1.1 Integration of electrical equipment and topside systems in floating substations under dynamic conditions

Design and integration of electrical equipment and topside systems for floating substations, addressing the installation, operation and interface requirements of transformers, power conversion equipment and switchgear under platform motions and dynamic offshore loads.

Technological Objective

To enable the reliable and safe operation of floating substations by adapting the integration, interfaces and functional arrangement of electrical equipment to platform motions, accelerations and dynamic offshore conditions.

Specific Actions

- Definition of functional and design requirements for electrical equipment integration on floating substations subject to motions, accelerations and dynamic loads
- Integration of transformers, converters, switchgear and auxiliary electrical systems considering dynamic behaviour and offshore operational constraints
- Assessment of electrical, mechanical and structural interfaces between topside equipment and floating platform systems
- Evaluation of operational limits, equipment tolerances and performance constraints associated with floating motions and dynamic environmental conditions

Validation and Trial Needs

- Validation of equipment integration concepts and operational performance through numerical analysis and component- or subsystem-level testing under representative motion, inclination and load conditions
- Demonstration of floating-specific electrical equipment integration and interface solutions using pilot-scale or representative test platforms, where applicable

Expected Results

- Reliable operation of electrical conversion and transmission equipment on floating substations under representative offshore dynamic conditions
- Reduced technical uncertainty and increased confidence in floating substation concepts for large-scale deployment

Current TRL

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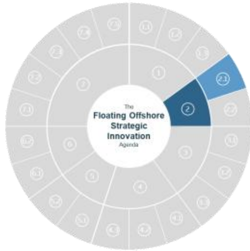
Current TRL					

Innovation Line Fact Sheet



Lifecycle Stage: Design and construction

Area 2: Electrical infrastructure and grid connection

Subarea 2.1: Floating substations and electrical conversion

2.1.2 Cooling and thermal management systems for offshore electrical equipment

Development and adaptation of cooling and thermal management solutions for electrical equipment installed offshore, with specific focus on floating substations operating in dynamic marine environments.

Technological Objective

To ensure reliable operation and extended service life of offshore electrical equipment by implementing cooling and thermal management systems robust to platform motions, ambient marine conditions and variable electrical loading.

Specific Actions

- Assessment of thermal loads and heat dissipation requirements for key offshore electrical equipment under floating operation
- Development and adaptation of cooling concepts suitable for dynamic environments (for example, air, liquid or hybrid systems)
- Evaluation of the impact of platform motions, inclination and accelerations on cooling performance and reliability
- Integration of thermal management solutions with floating substation layout and operational constraints

Validation and Trial Needs

- Laboratory testing of cooling systems under representative thermal loads and dynamic conditions
- Validation of thermal performance and reliability through pilot-scale demonstrations or representative offshore test platforms

Expected Results

- Improved reliability and lifetime of offshore electrical equipment
- Reduced risk of overheating-related failures and operational restrictions in floating substations

Current TRL

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Current TRL					

Innovation Line
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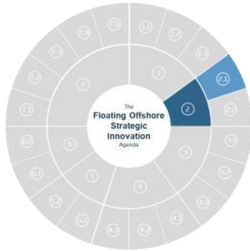

Lifecycle Stage: Design and construction

Area 2: Electrical infrastructure and grid connection

Subarea 2.1: Floating substations and electrical conversion

2.1.3 Protection and control systems for dynamic electrical systems

Development and adaptation of protection and control systems for electrical infrastructure operating on floating platforms, addressing the challenges introduced by platform motions, dynamic loads, variable operating conditions and transient or abnormal platform displacements.

Technological Objective

To ensure safe, reliable and selective protection of electrical systems in floating wind applications by adapting protection schemes and control strategies to dynamic behaviour and non-stationary operating conditions.

Specific Actions

- Assessment of the impact of platform motions and dynamic behaviour on the performance of existing electrical protection schemes
- Adaptation of protection and disconnection strategies, including sensing and threshold settings, to electrical systems subject to movement
- Evaluation of protection selectivity and robustness under dynamic operating conditions

Validation and Trial Needs

- Simulation and testing of protection and control systems under representative dynamic electrical and mechanical conditions
- Validation of protection performance and coordination through pilot-scale demonstrations or representative test platforms

Expected Results

- Reliable fault detection and disconnection under dynamic operating conditions
- Reduced risk of false trips and improved operational continuity of floating electrical systems

Current TRL

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Innovation Line
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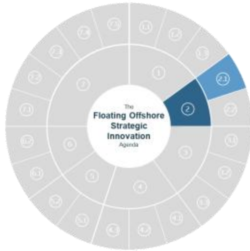

Lifecycle Stage: Design and construction

Area 2: Electrical infrastructure and grid connection

Subarea 2.1: Floating substations and electrical conversion

2.1.4 Optimisation of intra-array electrical layouts for floating wind farms

Design and optimisation of intra-array electrical architectures for floating wind, combining dynamic and static cable routing, protection and installation constraints. The line targets layout solutions that minimise total cable and installation cost while ensuring electrical performance and long-term reliability under floating-specific motions, offsets and seabed interaction conditions, including interfaces with floating substations and export system configurations where relevant.

Technological Objective

To reduce floating wind plant LCoE by optimising intra-array cable layouts (dynamic + static sections) that meet electrical, mechanical and installation constraints while improving reliability, maintainability and cost performance

Specific Actions

- Develop layout optimisation solutions integrating electrical design (topology, losses, redundancy) with dynamic cable constraints (offsets, fatigue drivers, bend limits)
- Integrate route engineering and seabed constraints (bathymetry, geohazards, crossings, burial/protection) into early-stage layout tools and rules
- Define adaptable layout configurations and design guidelines for typical floating wind farm conditions, including floater spacing, mooring patterns and electrical system voltage levels
- Assessment of integration constraints and reliability implications associated with floating substations and dynamic export cable interfaces where applicable

Validation and Trial Needs

- Verification via coupled analyses of representative layouts (electrical performance + mechanical response/fatigue) under project metocean conditions
- Benchmarking against baseline layouts to quantify cost, installation time and reliability improvements
- Demonstration in FEED / project case studies including installation methodology, protection design and maintainability assessment
- Validation of cost impacts of optimised layouts, including CAPEX, installation and lifecycle cost assessments under representative conditions

Expected Results

- Cost-optimised intra-array layouts reducing cable length, protection scope and installation complexity
- Improved reliability through reduced fatigue exposure and better interface/route design
- Repeatable design guidance and tools supporting faster FEED and reduced redesign iterations

Current TRL

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Innovation Line
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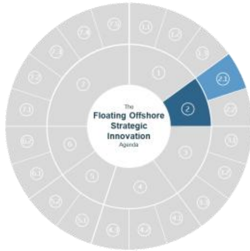

Lifecycle Stage: Design and construction

Area 2: Electrical infrastructure and grid connection

Subarea 2.1: Floating substations and electrical conversion

2.1.5 Technological challenge related to the development of electrical switchgear for DC applications in offshore substations

Development and qualification of DC switchgear technologies for offshore substations (incl. floating substations) to enable reliable protection, isolation and operability in HVDC transmission and collection systems. The line addresses DC-specific challenges (fast fault interruption, protection selectivity, insulation/arc management) and offshore constraints (SWaP, marine environment, maintainability), targeting industrial-ready solutions for far-offshore projects.

Technological Objective

To enable safe and reliable offshore HVDC operation by developing DC switchgear and protection functions capable of fast fault detection and interruption, suitable for integration in offshore (floating) substations and compatible with lifecycle O&M requirements.

Specific Actions

- Develop DC switchgear concepts (breakers, disconnectors, earthing/isolators) adapted to HVDC fault behaviour and offshore SWaP constraints
- Engineer insulation systems, arc/quenching and thermal management suitable for marine environments and high availability targets
- Define integration requirements and qualification routes (interfaces with converters, protection/control, redundancy, maintainability)

Validation and Trial Needs

- Type/qualification testing under representative HVDC fault scenarios (interruption capability, dielectric withstand, endurance)
- Integration trials with HVDC protection and control to validate speed, selectivity and operational procedures
- Demonstration in an offshore-relevant setup (substation mock-up/pilot), including maintainability and safety case validation

Expected Results

- Qualified offshore-ready DC switchgear enabling HVDC protection and isolation in offshore substations
- Reduced technical risk and improved availability for far-offshore HVDC export solutions
- Standardized specifications and qualification pathway supporting industrial deployment

Current TRL

	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Current TRL	■	□	□	□	□

Innovation Line
Fact Sheet

Lifecycle Stage: Design and construction

Area 2: Electrical infrastructure and grid connection

Subarea 2.2: Grid management and stability for floating wind farms

2.2.1 Electrical stability analysis tools for floating wind farms

Development and application of electrical stability analysis tools tailored to floating wind farms, enabling the assessment of system stability under dynamic operating conditions and accounting for the interaction between wind generation, power electronic conversion and the onshore grid.

Technological Objective

To improve the capability to assess and predict electrical stability phenomena in floating wind farms by adapting and applying existing analysis tools to floating-specific operating conditions and grid interactions.

Specific Actions

- Identification of relevant electrical stability phenomena in floating wind farms and assessment of their implications for electrical design decisions, equipment specification and operating conditions
- Development or adaptation of modelling approaches suitable for analysing electrical stability in systems with high penetration of converter-based generation
- Integration of floating wind-specific characteristics into stability analysis tools, including variability in operating conditions and interaction with offshore and onshore grid infrastructure

Validation and Trial Needs

- Validation of stability analysis tools against representative floating wind farm configurations and grid connection scenarios
- Comparison of analysis results with available operational data or detailed simulation benchmarks to assess model credibility
- Validation of the effectiveness of representative control strategies and mitigation approaches for managing floating-specific electrical stability issues

Expected Results

- Improved capability to identify potential electrical stability issues at early design stages
- Increased confidence in grid connection studies and system integration of floating wind farms

Current TRL

	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Current TRL	■	□	□	□	□

Innovation Line
Fact Sheet

Lifecycle Stage: Design and construction

Area 2: Electrical infrastructure and grid connection

Subarea 2.2: Grid management and stability for floating wind farms

2.2.2 Plant control strategies to reduce electro-mechanical interactions

Development and adaptation of plant-level control strategies for floating wind farms aimed at mitigating electro-mechanical interactions between wind turbines, electrical infrastructure and floating platforms under dynamic operating and grid conditions, including improved measurement architectures and reliable monitoring systems supporting coordinated control.

Technological Objective

To enhance the electrical stability and operational robustness of floating wind farms by coordinating turbine, electrical system and substation controls, supported by improved measurement architectures and reliable monitoring of electro-mechanical interactions.

Specific Actions

- Identification of electro-mechanical interaction mechanisms in floating wind farms, including measurement requirements and monitoring architectures needed to support plant-level control strategies
- Development of coordinated plant-level control strategies linking wind turbine controls, electrical systems and offshore substations
- Assessment of control trade-offs between electrical stability, mechanical loads and power quality

Validation and Trial Needs

- Validation of coordinated plant-level control strategies through integrated electro-mechanical simulations representative of floating wind farm operation
- Assessment of control effectiveness using representative case studies and, where available, data from pilot or demonstration floating wind projects

Expected Results

- Reduced adverse electro-mechanical interactions affecting floating wind farm operation
- Improved electrical stability and reduced dynamic loading through coordinated plant control strategies

Current TRL

	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Current TRL	■	■	□	□	□

Innovation Line Fact Sheet

Lifecycle Stage: Design and construction

Area 2: Electrical infrastructure and grid connection

Subarea 2.2: Grid management and stability for floating wind farms

2.2.3 Grid- forming capabilities and energy storage integration for floating wind farms

Development and integration of grid-forming (GFM) control capabilities and energy storage systems (ESS) for floating wind farms to provide stable voltage/frequency support and improved dynamic performance under weak-grid and far-offshore conditions. The line targets converter control functions, protection coordination and ESS sizing/architecture to deliver services such as inertia emulation, fast frequency response, voltage support, fault ride-through and power smoothing, while ensuring offshore operability and industrial deployment readiness

Technological Objective

To enable stable and compliant grid connection of floating wind farms in weak-grid/HVDC-linked scenarios by deploying grid-forming control strategies and integrated energy storage solutions that deliver required grid services and improve system resilience.

Specific Actions

- Develop and tune grid-forming control strategies for wind farm converters (WTGs, STATCOM/HVDC interfaces), including interoperability and multi-converter coordination
- Define ESS integration architectures (centralised vs distributed, DC-coupled vs AC-coupled) and sizing rules linked to target grid services and offshore constraints (SWaP, availability)
- Establish protection, stability and compliance design rules (fault behaviour, ride-through, harmonics, black-start/restoration where applicable) for combined GFM + ESS systems

Validation and Trial Needs

- EMT-level simulations and hardware-in-the-loop validation to demonstrate stability and performance under weak-grid and fault scenarios
- Verification of coordinated operation (GFM + ESS + farm-level controller) including protection selectivity and interactions with HVDC/offshore substation controls
- Pilot demonstration in a representative environment (test site or project pilot) validating performance KPIs, availability and O&M procedures

Expected Results

- Proven GFM control packages and integration guidelines enabling floating wind operation in weak-grid conditions
- ESS integration solutions delivering frequency/voltage services, smoothing and improved ride-through performance
- Reduced curtailment and improved compliance, supporting higher penetration and bankability of far-offshore floating wind

Current TRL

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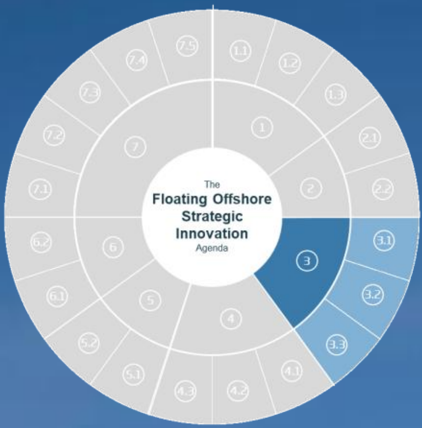

Area 3 - Wind turbine, tower or alternative supporting structures and FOW-specific control

Innovation Line
Fact Sheet

Lifecycle Stage: Design and construction

Area 3: Wind turbine, tower or alternative supporting structures and FOW-specific control

Subarea 3.1: Adaptation of the wind turbine (WTG) and tower to floating foundation

3.1.1 Adaptive stiffness / Load-tuned structural designs and segmented concepts for floating applications in all phases of the lifecycle

Development and assessment of adaptive stiffness and load-tuned structural designs and segmented supporting structure concepts (tower or alternative supporting structures) for floating wind applications, aiming to optimise global structural stiffness, damping behaviour and load distribution while facilitating transport, integration, installation and lifecycle operation.

Technological Objective

To improve the structural and dynamic performance and installability of wind turbine supporting structures for floating wind by optimising stiffness, damping behaviour and load distribution, while enabling modular or segmented configurations compatible with floating foundation constraints across the lifecycle.

Specific Actions

- Assessment of global stiffness and damping requirements for wind turbine supporting structures in floating applications, building on existing offshore and onshore tower design practices
- Development and evaluation of segmented and modular supporting structure configurations optimised for floating wind, including load-tuned stiffness distribution, vibration mitigation and structural performance
- Investigation of damping enhancement concepts for floating wind supporting structures, including integrated or retrofit-compatible vibration control approaches
- Evaluation of transport, integration and installation implications of segmented designs under realistic offshore deployment scenarios

Validation and Trial Needs

- Numerical validation of structural and dynamic response under representative floating wind load cases
- Experimental evaluation of damping behaviour in representative supporting structures and floating components to support model calibration and validation
- Numerical assessment of damping enhancement concepts and vibration mitigation strategies to evaluate feasibility and impact on structural response and fatigue behaviour

Expected Results

- Supporting structure designs with optimised stiffness, damping behaviour and reduced structural loads
- Improved reliability of vibration and dynamic response prediction models for floating wind supporting structures
- Improved transportability, installation flexibility and integration with floating foundations
- Availability of validated damping enhancement approaches for vibration control and fatigue reduction

Current TRL

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Current TRL	■	■	□	□	□

Innovation Line
Fact Sheet

Lifecycle Stage: Design and construction

Area 3: Wind turbine, tower or alternative supporting structures and FOW-specific control

Subarea 3.1: Adaptation of the wind turbine (WTG) and tower to floating foundation

3.1.2 Aerodynamic and aero-structural optimisation of wind turbines and blades for floating platforms

Development and assessment of aerodynamic and aero-structural optimisation approaches for wind turbines and blades in floating applications, aiming to mitigate motion-induced loads, reduce fatigue, improve power capture and enhance overall turbine reliability under coupled aero-hydrodynamic conditions.

Technological Objective

To improve aerodynamic performance, structural integrity and fatigue behaviour of floating wind turbines by optimising aerodynamic and aero-structural blade designs, accounting for damping behaviour and tower-blade-platform interactions in order to mitigate platform-induced loads and dynamic coupling under floating operating conditions.

Specific Actions

- Identification of blade load drivers specific to floating wind conditions, including platform motions, coupled dynamics, tower stiffness interactions and vibration-related effects
- Assessment of aerodynamic and aero-structural blade design adaptations, including damping-related approaches, to mitigate motion-induced loads while maintaining or improving power capture and fatigue performance
- Evaluation of trade-offs between aerodynamic performance, structural response and fatigue life in floating-specific blade designs
- Investigation of blade damping behaviour and potential damping treatment concepts to reduce vibration coupling effects and fatigue damage in floating wind applications

Validation and Trial Needs

- Numerical validation of adapted blade designs using coupled aero-elastic models representative of floating wind operation
- Verification of fatigue load reductions and vibration behaviour through comparative analysis against baseline blade designs
- Validation of coupled aero-elastic blade models through basin-scale testing under representative coupled wind-wave operational conditions
- Experimental and numerical evaluation of blade damping behaviour and damping-related mitigation concepts under representative operational conditions
- Comparative fatigue testing of turbine blades versus baseline designs under representative wave and current conditions (e.g. wave/current test rigs or hybrid testing environments)

Expected Results

- Reduced motion-induced loads, vibration coupling effects and fatigue damage while maintaining or improving aerodynamic power capture in floating wind turbine blades
- Improved blade reliability, vibration robustness and lifetime under floating-specific operating conditions

Current TRL

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Current TRL	□	■	□	□	□

Innovation Line
Fact Sheet

Lifecycle Stage: Design and construction

Area 3: Wind turbine, tower or alternative supporting structures and FOW-specific control

Subarea 3.1: Adaptation of the wind turbine (WTG) and tower to floating foundation

3.1.3 Standardised interfaces between wind turbine and floater

Development of standardised technical interfaces between the wind turbine (WTG) and the floating substructure, enabling consistent mechanical, structural and functional integration across different floating wind concepts while reducing project-specific customisation, simplifying integration requirements and supporting interoperability and accelerated deployment.

Technological Objective

To facilitate co-design, scalability and industrial integration of wind turbines and floating substructures by defining common interface requirements and adaptable connection approaches that improve compatibility, reduce integration risks and support reliable, low-maintenance integration across floating wind projects, while maintaining sufficient flexibility to avoid constraining innovation.

Specific Actions

- Identification of critical mechanical, structural and functional interface requirements between WTG and floating substructures
- Development of standardised interface specifications addressing load transfer, tolerances, integration constraints, accessibility and maintainability requirements
- Assessment of interface concepts across representative turbine and floater configurations to ensure broad applicability and compatibility with different supporting structure concepts
- Investigation of connection approaches enabling simplified installation, reduced external intervention requirements and low-maintenance operation

Validation and Trial Needs

- Numerical validation of standardised interface concepts under representative floating wind load cases
- Scale testing of representative connection concepts to verify load-transfer capacity, structural behaviour and maintainability assumptions
- Demonstration of interface compatibility through application to multiple turbine–floater integration scenarios
- Definition of an evolutionary approach for interface standardisation, including progressive validation and industry engagement to ensure applicability and sector-wide adoption

Expected Results

- Reduced integration effort and technical risk between wind turbines and floating substructures
- Increased flexibility to combine different turbine and floater designs, supporting scalability and industrial deployment

Current TRL

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Innovation Line
Fact Sheet

Lifecycle Stage: Design and construction

Area 3: Wind turbine, tower or alternative supporting structures and FOW-specific control

Subarea 3.1: Adaptation of the wind turbine (WTG) and tower to floating foundation

3.1.4 Materials and coatings for wind turbine and tower in floating environments

Development and application of materials and protective coating solutions for wind turbine components and towers operating in floating offshore environments, aimed at improving durability, reducing degradation under harsh marine conditions and ensuring compliance with environmental regulations.

Technological Objective

To enhance the long-term durability and availability of wind turbines in floating wind applications by reducing corrosion, wear and material degradation while ensuring compatibility with environmental regulations governing offshore materials and coatings.

Specific Actions

- Identification of dominant degradation mechanisms affecting wind turbine and tower materials in floating offshore environments
- Assessment of advanced materials and coating solutions suitable for long-term exposure to marine conditions and dynamic operation
- Evaluation of compatibility between materials, coatings, manufacturing or repair processes and environmental regulations applicable to offshore wind applications

Validation and Trial Needs

- Laboratory testing of materials and coatings under representative marine exposure and mechanical loading conditions
- Validation of durability and performance through long-term exposure testing, including accelerated ageing approaches and, where feasible, pilot-scale offshore applications

Expected Results

- Improved resistance to corrosion and environmental degradation of wind turbine and tower components
- Reduced maintenance requirements and increased service life in floating wind environments

Current TRL

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Current TRL					

Innovation Line
Fact Sheet

Lifecycle Stage: Design and construction

Area 3: Wind turbine, tower or alternative supporting structures and FOW-specific control

Subarea 3.1: Adaptation of the wind turbine (WTG) and tower to floating foundation

3.1.5 O&M-oriented design of the wind turbine and tower for offshore applications

Development and application of O&M-oriented design criteria for wind turbines and towers in offshore and floating wind applications, focusing on improving accessibility, reducing intervention complexity and enabling efficient inspection, maintenance, repair and replacement of key components throughout the asset lifecycle.

Technological Objective

To reduce operational complexity, downtime and lifecycle costs of floating wind turbines by integrating O&M considerations into the design of the wind turbine and tower from early design stages.

Specific Actions

- Identification of O&M-critical components and activities specific to floating wind turbines and towers
- Definition of design features that facilitate offshore access, inspection and maintenance under floating conditions
- Assessment of design trade-offs between structural performance, accessibility and maintainability
- Definition of key performance indicators (KPIs) for O&M-oriented design (e.g. intervention time, accessibility, component replacement strategies) to support design optimisation and benchmarking

Validation and Trial Needs

- Validation of O&M-oriented design solutions through simulated offshore maintenance scenarios and representative case studies
- Demonstration of improved accessibility and maintainability in pilot-scale or demonstration floating wind projects, including, where feasible, pilot maintenance exercises

Expected Results

- Reduced offshore intervention time and operational downtime
- Improved safety, accessibility and efficiency of maintenance activities in floating wind applications

Current TRL

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Current TRL		■			

Innovation Line
Fact Sheet

Lifecycle Stage: Design and construction

Area 3: Wind turbine, tower or alternative supporting structures and FOW-specific control

Subarea 3.1: Adaptation of the wind turbine (WTG) and tower to floating foundation

3.1.6 Adaptation of wind turbine design and control to floating platform dynamics

Adaptation of wind turbine design features and control strategies to floating wind concepts characterised by platform-induced motions and dynamic responses, including yaw behaviour, passive or semi-passive platform alignment effects and floating-specific operational conditions.

Technological Objective

To ensure stable and efficient operation of wind turbines installed on floating platforms by adapting turbine design and control strategies to platform-induced motions and dynamic response, accounting for the impact of yaw behaviour and floating platform dynamics on control performance, structural loading and operational stability.

Specific Actions

- Identification of dynamic and control challenges associated with floating platform motions, yaw behaviour and floating-specific operating conditions
- Adaptation of wind turbine design and control strategies, including pitch and yaw control interactions, to improve stability, load mitigation and operational performance on floating platforms
- Assessment of interactions between platform motions, turbine control response and structural loading under representative floating wind operating conditions

Validation and Trial Needs

- Validation of adapted turbine design and control strategies through advanced coupled aero-hydro-servo simulations representative of floating wind concepts
- Assessment of control performance, platform response and load mitigation using representative case studies and demonstrator data where available
- Targeted control simulation studies under representative floating operational conditions, complemented where possible by pilot-scale testing

Expected Results

- Improved stability and operational performance of floating wind turbines under platform-induced motions
- Reduced structural loads and improved interaction management between turbine control systems and floating platform dynamics

Current TRL

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Current TRL					

Innovation Line
Fact Sheet

Lifecycle Stage: Design and construction

Area 3: Wind turbine, tower or alternative supporting structures and FOW-specific control

Subarea 3.1: Adaptation of the wind turbine (WTG) and tower to floating foundation

3.1.7 Process-oriented standardisation and modular manufacturing of wind turbine components to facilitate integration with floating foundations and accommodate design variability

Development of process-oriented standardisation and modular manufacturing approaches for wind turbine and tower components to simplify and accelerate integration with floating foundations. The line targets standardised interfaces, modular sub-assemblies and repeatable manufacturing/assembly processes that can accommodate design variability (turbine models, tower geometries, floater interface requirements) while improving industrial scalability, quality and integration performance.

Technological Objective

To reduce integration time, risk and cost by standardising WTG/tower–floater interfaces and enabling modular, repeatable manufacturing and assembly processes that remain compatible with different floating foundation concepts and turbine configurations.

Specific Actions

- Define standardised mechanical and functional interfaces for WTG/tower integration with floaters (load paths, flange/joint concepts, tolerances, installation constraints)
- Establish process standards and design rules enabling interchangeability and configuration management across turbine variants and floating foundation requirements, supporting alignment across stakeholders
- Develop modular component architectures and manufacturing/assembly sequences (transportable submodules, pre-assembly, QA/QC standard procedures)
- Assessment of cost-benefit trade-offs between modular and bespoke design and manufacturing approaches for different floating wind deployment scenarios

Validation and Trial Needs

- Industrial trials of modular manufacturing and assembly processes (repeatability, tolerances, cycle time, QA/QC performance)
- Interface fit-up and load-transfer verification (structural checks, fatigue screening) across representative configuration variants
- Demonstration in an integration pilot (port-side integration and installation readiness) validating logistics, handling and schedule benefits

Expected Results

- Standardised interface specifications enabling faster WTG/tower–floater integration across projects
- Modular manufacturing processes reducing production time, rework and integration risk while improving scalability
- Improved flexibility to accommodate design variability (turbine supplier choices, upscaling) without major process redesign

Current TRL

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Innovation Line
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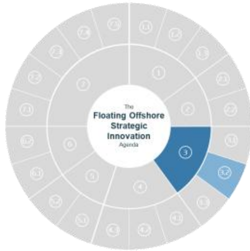

Lifecycle Stage: Design and construction

Area 3: Wind turbine, tower or alternative supporting structures and FOW-specific control

Subarea 3.2: Control and dynamic behaviour of the floating system

3.2.1 Model based and feedforward control strategies integrated into existing systems

Development and application of model-based and feedforward control strategies for floating wind systems, integrated into existing turbine and platform control architectures. These strategies combine wind, wave and platform motion information to anticipate system response and reduce structural loads and motions under dynamic operating conditions.

Technological Objective

To enhance the dynamic performance and operational robustness of floating wind turbines by improving load mitigation and motion control through model-based and anticipative control strategies compatible with existing turbine and platform control systems, including pitch, yaw and generator load control approaches, while accounting for uncertainties in environmental input data.

Specific Actions

- Identification of key load and motion drivers in floating wind systems that can be effectively addressed through predictive or feedforward control approaches
- Adaptation and tuning of model-based, predictive and feedforward control algorithms incorporating wind, wave and platform motion information, including pitch, yaw and generator load control functions.
- Integration of these control strategies within existing turbine and platform control frameworks, ensuring stability and compatibility with standard operational modes
- Integration and assessment of ahead-sensing technologies (e.g. nacelle-mounted lidar or radar systems) to support predictive and feedforward control strategies

Validation and Trial Needs

- Validation of predictive and feedforward control strategies through advanced coupled aero-hydro-servo simulations representative of floating wind operating conditions, including the use of measured or ahead-sensed input data where available
- Comparative assessment of load and motion reduction performance against baseline control strategies using representative floating wind case studies
- Where applicable, verification of control performance using data from pilot or demonstration floating wind projects

Expected Results

- Reduced dynamic loads and platform motions under normal and demanding operating conditions
- Improved overall system stability and fatigue performance without increasing control complexity or operational risk
- Increased confidence in the use of anticipative control strategies for floating wind applications

Current TRL

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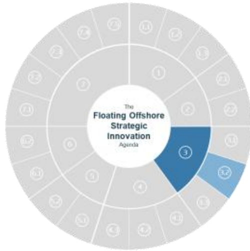
Current TRL					

Innovation Line
Fact Sheet



Lifecycle Stage: Design and construction

Area 3: Wind turbine, tower or alternative supporting structures and FOW-specific control

Subarea 3.2: Control and dynamic behaviour of the floating system

3.2.2 Operational implementation of motion-and operability-based (e.g. MOSE-type envelopes) criteria in control systems

Development and operational implementation of motion- and operability-based operational envelope criteria (e.g. MOSE-type envelopes) within floating wind control systems. These criteria define safe and efficient operating envelopes based on multiple coupled variables, supporting control decisions under demanding and highly dynamic operating conditions.

Technological Objective

To improve the operational robustness and safety of floating wind turbines by embedding motion- and operability-based multivariable operational envelopes into control systems, enabling informed and coordinated pitch, yaw and generator load control actions when approaching operational limits.

Specific Actions

- Definition of motion- and operability-based operational envelope criteria relevant to floating wind operation, considering coupled aerodynamic, hydrodynamic, structural and control-related variables
- Assessment of how MOSE-based control decisions interact with standard control modes, including power regulation, load mitigation and shutdown strategies
- Translation of MOSE criteria into control-relevant parameters and logic compatible with existing turbine and platform control architectures, including pitch, yaw and generator load control functions
- Definition and tuning of control strategies incorporating hysteresis, predictive shutdown criteria and re-start logic to improve operational stability and avoid unnecessary trips under transient conditions

Validation and Trial Needs

- Validation of MOSE-based control approaches through coupled aero-hydro-servo simulations covering normal, extreme and transient operating conditions
- Evaluation of control system behaviour near operational boundaries using representative floating wind case studies
- Where feasible, verification of MOSE implementation using data from pilot or demonstration floating wind projects

Expected Results

- Improved awareness of proximity to operational limits during floating wind operation
- More robust and coordinated control responses under demanding environmental conditions
- Reduced risk of unnecessary shutdowns or overly conservative operation while maintaining system safety

Current TRL

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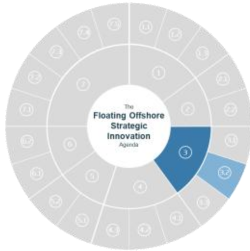
Innovation Line
Fact Sheet



Lifecycle Stage: Design and construction

Area 3: Wind turbine, tower or alternative supporting structures and FOW-specific control

Subarea 3.2: Control and dynamic behaviour of the floating system

3.2.3 Integrated co-control strategies for floater-turbine-mooring systems

Development and application of integrated coordinated control strategies that jointly consider the dynamic behaviour of the floating platform, the wind turbine and the mooring system. These co-control approaches aim to manage system-wide interactions and improve global stability, particularly under extreme or highly dynamic operating conditions.

Technological Objective

To improve the overall dynamic stability and resilience of floating wind systems by coordinating control actions across the turbine, floating substructure and mooring system, reducing adverse interactions and enhancing system response during demanding conditions.

Specific Actions

- Identification of key dynamic interactions between turbine control, platform motion and mooring system response that can benefit from coordinated control
- Development of co-control concepts that enable information exchange and coordinated actions between turbine, platform and mooring subsystems
- Assessment of control allocation strategies to balance load reduction, motion control and mooring system performance without compromising operational robustness
- Exploration of advanced coordination approaches, including data-driven and machine learning-based methods, to manage complex interactions between turbine, platform and mooring system dynamics

Validation and Trial Needs

- Validation of co-control strategies through fully coupled aero-hydro-servo-elastic simulations representative of floating wind systems
- Evaluation of system-level performance improvements under extreme events and transient conditions using representative floating wind case studies
- Where applicable, assessment of co-control concepts using data from pilot-scale or demonstration floating wind projects

Expected Results

- Improved global stability of the floating wind system under combined wind, wave and current loading
- Reduced adverse interactions between turbine control actions and mooring system response
- Enhanced capability to manage extreme events and transient operating conditions in floating wind applications

Current TRL

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Innovation Line
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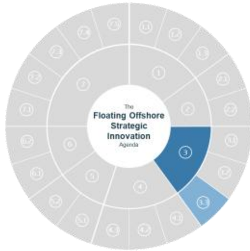

Lifecycle Stage: Design and construction

Area 3: Wind turbine, tower or alternative supporting structures and FOW-specific control

Subarea 3.3: Validation and aero-hydro-servo modelling for FOW

3.3.1 Reduced-order and modelling tools for rapid and early FOW design and optimisation

Development and application of validated reduced-order modelling tools to support rapid design assessment and optimisation of floating offshore wind (FOW) configurations. These tools enable fast evaluation of system behaviour, energy production performance and key design trade-offs during early design stages, supporting informed decision-making across a wide range of floating wind concepts.

Technological Objective

To improve the efficiency, consistency and robustness of early-stage floating wind design by enabling rapid, reliable assessment of system behaviour and performance using reduced-order models validated against higher-fidelity tools and experimental data.

Specific Actions

- Adaptation and refinement of existing reduced-order modelling approaches to capture the dominant aero-hydro-servo dynamics of floating wind systems, while assessing their applicability limits under highly non-linear or extreme operating conditions
- Validation of reduced-order models against high-fidelity numerical simulations and available experimental data for representative floating wind configurations
- Integration of reduced-order tools into early-stage design and optimisation workflows to support concept screening, trade-off analysis and identification of cases where higher-fidelity modelling provides added value

Validation and Trial Needs

- Benchmarking of reduced-order model predictions against detailed numerical models for a range of floating wind concepts and operating conditions, including assessment under non-linear and extreme scenarios
- Verification of model accuracy and robustness through comparison with data from scaled physical tests or demonstrator projects, where available

Expected Results

- Faster and more efficient assessment of floating wind design options during early project phases
- Improved consistency and transparency in concept comparison and optimisation studies
- Reduced reliance on computationally intensive simulations during preliminary design, while maintaining sufficient accuracy for decision-making and identifying conditions where advanced high-fidelity modelling becomes necessary

Current TRL

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Innovation Line
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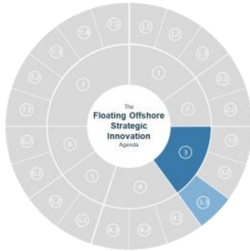

Lifecycle Stage: Design and construction

Area 3: Wind turbine, tower or alternative supporting structures and FOW-specific control

Subarea 3.3: Validation and aero-hydro-servo modelling for FOW

3.3.2 Scaled testing campaigns and numerical-experimental correlation frameworks

Design and execution of dedicated scaled testing campaigns for floating offshore wind systems, combined with systematic numerical–experimental correlation frameworks and validation activities. These campaigns aim to validate aero-hydro-servo modelling approaches and improve confidence in design tools through comparison between physical test data and numerical simulations.

Technological Objective

To increase the reliability and credibility of floating wind design and analysis tools by strengthening numerical-experimental correlation, supporting model validation, uncertainty reduction and improved design robustness.

Specific Actions

- Definition of representative scaled testing programmes addressing key floating wind load cases and dynamic response
- Execution of physical model tests under controlled laboratory conditions, including wind, wave and coupled loading scenarios
- Systematic comparison and calibration of numerical models against experimental results to identify model limitations and uncertainties

Validation and Trial Needs

- Benchmarking of reduced-order model predictions against detailed numerical models for a range of floating wind concepts and operating conditions
- Verification of model accuracy and robustness through comparison with data from scaled physical tests, demonstrator projects and shared benchmark datasets where available
- Assessment of scaling effects and application of appropriate similarity laws (e.g. Froude, Reynolds and Strouhal scaling), including uncertainty analysis to evaluate propagation of scaling-related errors and their impact on model validation and design robustness

Expected Results

- Improved confidence in numerical simulation tools used for floating wind design and assessment
- Reduced uncertainty in predicted loads, motions and dynamic response of floating wind systems
- Enhanced consistency between experimental testing and numerical modelling practices across the sector

Current TRL

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Current TRL					

Innovation Line
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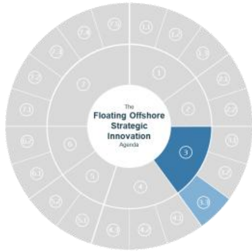

Lifecycle Stage: Design and construction

Area 3: Wind turbine, tower or alternative supporting structures and FOW-specific control

Subarea 3.3: Validation and aero-hydro-servo modelling for FOW

3.3.3 Guidelines for metocean binning and simulation lists for floating wind load analysis

Development of harmonised guidelines for metocean binning and the definition of simulation lists for floating offshore wind applications, to standardise the selection and combination of environmental conditions and load cases used in numerical simulations, while accounting for site-specific metocean characteristics and complex combined loading conditions relevant to floating wind systems.

Technological Objective

To improve consistency, transparency and comparability of floating wind design and validation studies by establishing common criteria for defining metocean bins and simulation sets accounting for floating wind operating conditions and combined environmental loading scenarios.

Specific Actions

- Review and consolidation of existing practices for metocean binning and simulation list definition used across floating wind projects and certification frameworks, ensuring alignment with relevant standards and industry practices
- Identification of key environmental parameters and combinations governing floating wind loads and dynamic behaviour, including directional misalignment effects and complex sea-state conditions where relevant
- Development of guideline-based approaches for defining representative and efficient simulation sets suitable for floating wind validation and assessment

Validation and Trial Needs

- Application of proposed guidelines to representative floating wind case studies to assess their adequacy and robustness under site-specific metocean conditions
- Comparison of results obtained using guideline-based simulation lists versus project-specific approaches, including the representation of combined environmental loading events
- Review and feedback from industry stakeholders and certification bodies to support acceptance and refinement of the guidelines

Expected Results

- Improved consistency in the definition of metocean conditions and simulation lists across floating wind projects
- Reduced variability in design and validation outcomes driven by methodological choices rather than technical performance
- Enhanced comparability and transparency of floating wind designs in validation and certification processes

Current TRL

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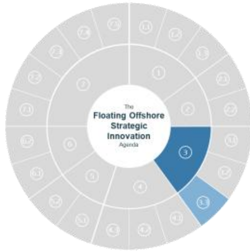
Innovation Line
Fact Sheet



Lifecycle Stage: Design and construction

Area 3: Wind turbine, tower or alternative supporting structures and FOW-specific control

Subarea 3.3: Validation and aero-hydro-servo modelling for FOW

3.3.4 Analysis of Small-Scale Turbines with Complex 3D Blade Shape

Development and validation of modelling and testing approaches for small-scale wind turbines featuring complex 3D blade geometries, aimed at improving the fidelity of aero-hydro-servo-elastic simulations and physical model tests for floating wind. The line focuses on capturing 3D aerodynamic effects, scaled Reynolds impacts, control interactions, tower–rotor coupling and platform motions to ensure that small-scale experimental results are representative and transferable to full-scale FOW design and validation.

Technological Objective

To improve the reliability of FOW validation campaigns by enabling accurate representation of complex 3D blade aerodynamics, tower–rotor–platform coupling and floating motions in small-scale turbines, ensuring scalable and traceable correlation between experimental results and full-scale aero-hydro-servo models.

Specific Actions

- Develop aerodynamic modelling approaches for complex 3D blade effects at model scale (3D corrections, Reynolds scaling strategies, unsteady aerodynamics)
- Integrate validated turbine and rotor models into coupled aero-hydro-servo-elastic frameworks, including representative tower stiffness and platform motion effects, for floating wind validation
- Define calibration procedures linking small-scale turbine behaviour (thrust, torque, control response and structural dynamics) to full-scale targets for FOW testing
- Develop and validate correlation methodologies between small-scale experimental data, numerical simulations and full-scale floating wind behaviour to improve extrapolation reliability and scaling consistency

Validation and Trial Needs

- Wind tunnel and/or towing basin tests with instrumented small-scale rotors and representative 6DoF platform motions to characterise aerodynamic polars, unsteady response and control behaviour
- Correlation of measured loads and performance with numerical models (BEM/CFD/hybrid) and Software-in-the-Loop approaches, including quantification of scaling uncertainty
- Round-robin or benchmark campaigns to demonstrate repeatability and transferability of methodologies across facilities and turbine designs
- Definition and application of scaling and correlation methodologies to ensure reliable extrapolation of test and simulation results to full-scale conditions

Expected Results

- Validated modelling guidelines for small-scale turbines with complex 3D blades in FOW testing
- Improved consistency between experimental validation data and aero-hydro-servo-elastic simulations used in design
- Reduced uncertainty when extrapolating model-scale results to full-scale FOW performance, loads and dynamic behaviour
- Enhanced capability to assess and compare advanced blade geometries and aeroelastic design concepts under representative floating wind condition

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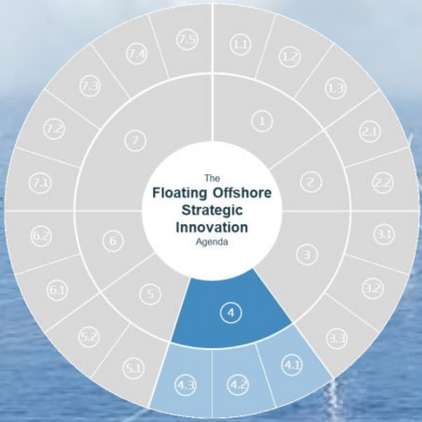

Area 4 - Wind farm layout design and site planning

Innovation Line
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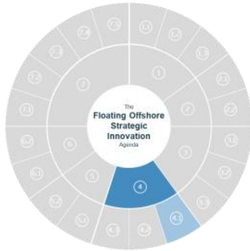

Lifecycle Stage: Design and construction

Area 4: Wind farm layout design and site planning

Subarea 4.1: Site characterisation and wind farm planning

4.1.1 Integrated characterisation of wind-wave-current resources

Integrated and site-specific characterisation of wind, wave and current resources at deep offshore locations, combining measurements, numerical models and reanalysis datasets into a harmonised metocean framework. This enables a robust understanding of coupled environmental conditions driving floating wind performance, loads, operability and energy yield assumptions, supporting informed decisions from early planning to detailed design.

Technological Objective

To improve the accuracy, consistency and physical coherence of resource assessments for floating offshore wind projects by integrating and harmonising existing wind, wave and current datasets and assessment tools, thereby supporting robust site selection, layout design and early-stage engineering decisions.

Specific Actions

- Inventory and assessment of existing wind, wave and current datasets, modelling tools and integration opportunities for floating wind site characterisation
- Investigation of coupled environmental processes (e.g. wind-wave misalignment, wave-current interaction and stratification effects) and their implications for floating wind resource characterisation and engineering assumptions
- Assessment of spatial and temporal variability of coupled metocean conditions relevant for floating wind deployment, including joint wind-wave-current extremes
- Evaluation of implications of combined wind-wave-current conditions on floating wind farm layout design, operability and engineering assumptions

Validation and Trial Needs

- Validation of integrated resource characterisation approaches through comparison with long-term measurement campaigns and representative offshore datasets where available
- Cross-checking of integrated datasets against independent modelling tools, historical offshore data and alternative reanalysis frameworks to assess robustness and consistency
- Validation under extreme and coupled metocean conditions to assess the capability of integrated datasets and models to represent rare events and joint environmental states
- Multi-site intercomparison and application of integrated characterisation methodologies across representative floating wind regions and metocean regimes

Expected Results

- More reliable, physically consistent and harmonised descriptions of offshore wind, wave and current conditions relevant to floating wind projects
- Reduced and better-quantified uncertainty in site selection, layout design, operability assessment and early-stage engineering assumptions
- Improved understanding and representation of coupled wind-wave-current conditions and extreme environmental states relevant to floating wind systems
- Improved comparability and transparency of site characterisation studies across different floating wind projects through aligned datasets, metrics and methodologies

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Innovation Line
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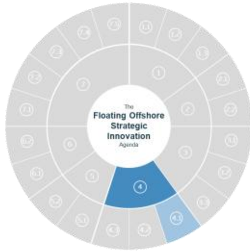

Lifecycle Stage: Design and construction

Area 4: Wind farm layout design and site planning

Subarea 4.1: Site characterisation and wind farm planning

4.1.2 Assessment of seabed-anchor interaction under complex conditions

Assessment of seabed-anchor interaction under complex geological and geotechnical conditions using integrated methodologies that combine site data, modelling and uncertainty analysis. The aim is to reduce uncertainties in site selection and mooring system design for floating wind projects, while improving understanding of anchor behaviour under long-term and cyclic loading conditions.

Technological Objective

To improve confidence in site suitability and mooring system performance by enhancing the assessment of seabed-anchor interaction under variable and uncertain offshore conditions, including implications for long-term anchoring behaviour, cyclic loading response and retention needs.

Specific Actions

- Integration of geophysical and geotechnical site data into standardised assessment workflows for seabed conditions relevant to floating wind anchoring systems
- Application and refinement of seabed-anchor interaction models for floating wind anchoring solutions under representative offshore loading conditions
- Investigation of cyclic and long-term loading effects on anchor performance, including degradation and creep behaviour
- Development of probabilistic and reliability-based design approaches to account for geotechnical uncertainty and spatial variability
- Evaluation of uncertainty drivers associated with seabed variability and their influence on anchor performance, reliability and design margins

Validation and Trial Needs

- Validation of seabed-anchor interaction assessment approaches through comparison with field data, laboratory tests and full-scale anchor test results where available
- Application of assessment methodologies to representative floating wind site studies to evaluate robustness and sensitivity to seabed uncertainties

Expected Results

- Reduced uncertainty in anchor selection and mooring system design at early project stages
- Improved alignment between site characterisation outcomes and anchoring design assumptions
- More robust and cost-effective anchoring solutions through better-informed site planning decisions and reliability-based assessment approaches

Current TRL

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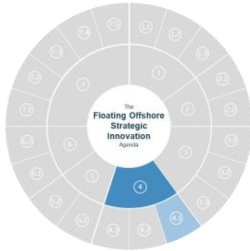

Lifecycle Stage: Design and construction

Area 4: Wind farm layout design and site planning

Subarea 4.1: Site characterisation and wind farm planning

4.1.3 Environmental risk assessment tools in the planning phase

Application and refinement of environmental risk assessment tools during the early planning stages of floating wind projects, enabling the systematic identification, characterisation and evaluation of potential environmental risks associated with site selection, wind farm layout design, export cable routing and infrastructure deployment, supporting environmentally informed planning and more sustainable project development.

Technological Objective

To support informed decision-making in floating wind project planning by identifying environmental risks at early stages, reducing uncertainty and facilitating environmentally responsible site selection, layout design, export cable routing and infrastructure deployment planning.

Specific Actions

- Adaptation of existing environmental assessment methodologies to account for floating wind-specific features such as mooring systems, dynamic cables and deep offshore locations
- Integration of environmental risk assessment tools into early-stage site planning, layout design and infrastructure deployment workflows, including implications for installation windows and weather-related constraints
- Development of approaches to screen and prioritise environmental risks based on their potential impact and likelihood

Validation and Trial Needs

- Application of environmental risk assessment tools to representative floating wind planning case studies to evaluate effectiveness, usability and relevance for early-stage decision-making
- Comparison of early-stage environmental risk assessments with outcomes from more detailed Environmental Impact Assessments (EIAs) where available, to assess consistency and identify gaps
- Structured review and feedback from regulatory authorities and environmental stakeholders to support validation, regulatory alignment and refinement of the assessment tools

Expected Results

- Earlier and more systematic identification of environmental risks relevant to floating wind projects
- Improved alignment between site planning decisions and environmental constraints, supporting more robust and environmentally informed project development
- Reduced likelihood of late-stage design changes, permitting delays or additional mitigation measures driven by previously unidentified environmental issues

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Innovation Line
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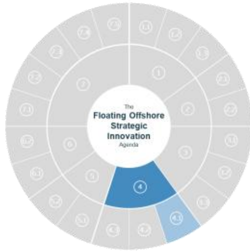

Lifecycle Stage: Design and construction

Area 4: Wind farm layout design and site planning

Subarea 4.1: Site characterisation and wind farm planning

4.1.4 Socio-economic analysis and maritime space use conflicts

Application and further development of socio-economic analysis and mapping tools to identify, assess and visualise potential conflicts and interactions between floating wind projects, adjacent floating wind developments and existing maritime uses at project and site level, within the boundaries and conditions established by existing marine spatial planning and regulatory frameworks. These tools facilitate informed site selection, optimise distribution and streamline the planning permission process by integrating spatial, socio-economic and sector-specific information relevant to the development of specific projects.

Technological Objective

To support strategic planning and decision-making for floating wind deployment by improving the identification and interpretation of socio-economic impacts and maritime space-use constraints at early project stages within existing planning and regulatory frameworks.

Specific Actions

- Integration of spatial datasets related to existing maritime activities, infrastructure and socio-economic factors relevant to specific floating wind project areas, consistent with approved marine spatial plans
- Development of mapping and visualisation approaches to assess project compatibility with existing maritime uses, planning constraints, stakeholder sensitivities and interactions between adjacent floating wind developments
- Assessment of how different layout and siting options influence socio-economic impacts and space-use interactions within predefined planning, licensing and cross-boundary marine spatial planning frameworks where relevant

Validation and Trial Needs

- Application of mapping tools to representative floating wind planning case studies to evaluate usability and decision-support value
- Comparison of mapping outputs with outcomes from stakeholder consultations and regulatory planning processes
- Review and feedback from relevant maritime stakeholders to refine mapping approaches and improve acceptance

Expected Results

- Improved visibility and understanding of potential socio-economic impacts and space-use conflicts associated with floating wind projects
- Better-informed site selection and layout decisions that reduce conflict risks, planning delays and cumulative interaction effects between adjacent developments
- Enhanced transparency and communication with stakeholders and authorities during the planning phase

Current TRL

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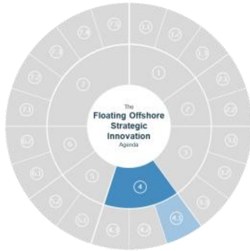
Innovation Line
Fact Sheet



Lifecycle Stage: Design and construction

Area 4: Wind farm layout design and site planning

Subarea 4.1: Site characterisation and wind farm planning

4.1.5 Co-location solutions and compatible uses of maritime space

Identification and assessment of co-location solutions and compatible uses of maritime space associated with floating wind projects, including multi-use concepts where appropriate. This line focuses on understanding technical, operational and planning conditions under which floating wind can coexist with other maritime activities.

Technological Objective

To enable more efficient and socially acceptable use of maritime space by identifying conditions and configurations that allow floating wind projects to coexist with other maritime uses without compromising safety, operability or project viability.

Specific Actions

- Identification of maritime activities with potential compatibility or partial co-location opportunities with floating wind projects
- Assessment of technical and operational constraints affecting co-location, including safety distances, access requirements, infrastructure interactions and military/naval operational considerations
- Evaluation of planning and regulatory considerations influencing the feasibility of co-location and multi-use concepts

Validation and Trial Needs

- Application of co-location assessment approaches to representative floating wind planning case studies
- Review of existing pilot projects or demonstrators involving multi-use or co-location concepts where available
- Engagement with relevant stakeholders, authorities and maritime users to assess practical feasibility, operational compatibility and acceptance

Expected Results

- Improved understanding of realistic co-location opportunities for floating wind projects
- Early identification of constraints and risks associated with multi-use of maritime space
- Better-informed planning decisions that balance floating wind deployment with other maritime activities

Current TRL

	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Current TRL					

Innovation Line
Fact Sheet

Lifecycle Stage: Design and construction

Area 4: Wind farm layout design and site planning

Subarea 4.2: Integrated wind farm design (co-design)

4.2.1 Integrated wake modelling solutions considering the movement of floaters

Development and application of wake modelling approaches for floating wind farms that explicitly account for the dynamic movement of floating platforms and the influence of mooring system stiffness on platform motion. These models aim to capture the impact of floater motions on wake generation, propagation and interaction at intra-farm and extra-farm (adjacent farms) scale.

Technological Objective

To improve the accuracy of energy yield estimation and layout design for floating wind farms by incorporating the effects of floater motion and mooring system stiffness into wake modelling and farm-level performance assessment.

Specific Actions

- Identification of floater motion characteristics and mooring system stiffness parameters that significantly influence wake behaviour in floating wind farms
- Adaptation of existing wake modelling approaches to include the effects of platform motion and orientation variability
- Integration of motion-aware wake models into wind farm analysis and layout design workflows, including assessment of adjacent-farm interaction effects

Validation and Trial Needs

- Validation of motion-aware wake models through comparison with high-fidelity simulations or experimental data where available
- Sensitivity studies to assess the impact of platform motion assumptions on wake interaction and energy yield predictions
- Application of integrated wake modelling approaches to representative floating wind farm case studies

Expected Results

- Improved prediction of wake effects and energy production in floating wind farms
- More robust layout design decisions that account for platform motion and its influence on wake interactions
- Reduced uncertainty in farm-level performance assessments for floating wind projects

Current TRL

	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Current TRL					

Innovation Line
Fact Sheet

Lifecycle Stage: Design and construction

Area 4: Wind farm layout design and site planning

Subarea 4.2: Integrated wind farm design (co-design)

4.2.2 Layout optimisation considering movement ranges and mooring footprint

Optimisation of floating wind farm layouts considering the allowable movement ranges of floating platforms and the spatial footprint of mooring systems. This line addresses the integration of dynamic platform displacement and mooring constraints into wind farm layout design.

Technological Objective

To improve floating wind farm layout efficiency and feasibility by explicitly accounting for platform movement envelopes and mooring system footprints during layout optimisation and site planning.

Specific Actions

- Characterisation of typical platform movement ranges and mooring footprints for representative floating wind configurations
- Integration of movement envelopes and mooring constraints into layout optimisation algorithms and design workflows
- Evaluation of trade-offs between layout density, energy production, mooring system complexity and spatial constraints

Validation and Trial Needs

- Application of layout optimisation approaches to representative floating wind farm case studies considering realistic movement and mooring constraints
- Sensitivity analysis to assess the impact of movement ranges and mooring footprints on layout performance and feasibility
- Comparison of optimised layouts against conventional approaches that neglect dynamic displacement effects

Expected Results

- Layout designs that better reflect the physical space required by floating platforms and their mooring systems
- Reduced risk of spatial conflicts between neighbouring platforms, moorings and other infrastructure
- More realistic and robust wind farm layouts supporting efficient deployment of floating wind projects

Current TRL

	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Current TRL					

Innovation Line
Fact Sheet

Lifecycle Stage: Design and construction

Area 4: Wind farm layout design and site planning

Subarea 4.2: Integrated wind farm design (co-design)

4.2.3 Multi-disciplinary tools for floater-mooring-cabling-layout co-optimisation

Development and application of integrated multi-disciplinary design tools to support the farm-level co-optimisation of floating platforms, mooring systems, cable corridors and wind farm layout. These tools enable evaluation of complete floating wind farm configurations, capturing key interactions and trade-offs across disciplines without duplicating component-level optimisation tasks.

Technological Objective

To improve the overall efficiency, feasibility and robustness of floating wind farm designs by enabling coordinated farm-level optimisation across floating platforms, mooring systems, cable routing and layout configuration, including trade-offs between performance, cost, installability and replaceability.

Specific Actions

- Integration of existing disciplinary design tools for floaters, moorings, dynamic cables and layout analysis into coordinated design workflows
- Identification and representation of key interactions and constraints across disciplines that influence farm-level performance and feasibility
- Development of co-optimisation approaches to evaluate trade-offs between energy yield, structural performance, installation complexity, lifecycle cost, replaceability and spatial constraints

Validation and Trial Needs

- Application of multi-disciplinary co-optimisation tools to representative floating wind farm case studies
- Comparison of integrated co-optimisation results with sequential or discipline-by-discipline design approaches
- Sensitivity analysis to assess the robustness of co-optimised solutions to key design assumptions and uncertainties

Expected Results

- More coherent and realistic floating wind farm designs accounting for cross-disciplinary interactions
- Reduced risk of late-stage design conflicts between platforms, moorings, cabling and layout
- Improved ability to identify balanced farm-level solutions that optimise performance, cost, feasibility and replaceability

Current TRL

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Innovation Line
Fact Sheet

Lifecycle Stage: Design and construction

Area 4: Wind farm layout design and site planning

Subarea 4.2: Integrated wind farm design (co-design)

4.2.4 Anchor and mooring line sharing strategies between platforms

Assessment and development of anchor and mooring line sharing strategies between floating wind platforms to reduce material use, installation effort and environmental footprint of mooring systems. This line focuses on identifying conditions under which shared anchoring and mooring configurations can be safely and efficiently implemented at wind farm scale.

Technological Objective

To improve the efficiency and sustainability of floating wind mooring systems by enabling the use of shared anchors and mooring line configurations across multiple floating platforms where technically and operationally feasible.

Specific Actions

- Identification of floating wind configurations and site conditions suitable for anchor sharing solutions
- Assessment of load sharing mechanisms and load redistribution effects in shared anchoring and mooring line configurations across multiple floating platforms
- Evaluation of design, installation and operational implications of anchor sharing at wind farm scale

Validation and Trial Needs

- Application of anchor sharing concepts to representative floating wind farm layout and mooring design case studies
- Comparative analysis of shared versus individual anchoring solutions in terms of loads, redundancy, installation complexity and environmental impact
- Where available, review of relevant offshore experience or pilot applications involving shared anchoring concepts

Expected Results

- Reduced number of anchors and mooring components and associated seabed footprint in floating wind farms
- Improved material efficiency and potential cost reductions in mooring systems
- Clear understanding of technical and operational constraints governing the feasibility of anchor sharing

Current TRL

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Innovation Line
Fact Sheet

Lifecycle Stage: Design and construction

Area 4: Wind farm layout design and site planning

Subarea 4.3: Environment impact and ecosystem effect mitigation

4.3.1 Advanced tools for predicting and assessing environmental and socio-ecological impacts of floating wind farms, including ecosystem service interactions

Application and enhancement of advanced tools and methodologies for predicting and assessing environmental and socio-ecological impacts associated with floating wind projects, including impacts linked to floating-specific infrastructure, marine ecosystem interactions and ecosystem services. These solutions support early identification, evaluation and management of potential impacts throughout the planning and design phases.

Technological Objective

To improve the accuracy, consistency and usefulness of impact assessment tools for floating wind projects by applying advanced predictive approaches that account for floating-specific infrastructure, operational characteristics and interactions with marine ecosystems and ecosystem services.

Specific Actions

- Adaptation of existing environmental impact assessment models to incorporate floating wind-specific elements such as mooring systems, anchors, floating substructures, offshore footprints and their interactions with marine ecosystems and ecosystem services
- Integration of predictive environmental tools into early-stage project planning and design workflows
- Assessment of cumulative and combined impacts associated with floating wind farm deployment

Validation and Trial Needs

- Application of advanced environmental impact assessment tools to representative floating wind planning case studies
- Comparison of predicted impacts with outcomes from monitoring data and environmental studies where available
- Review of assessment approaches with environmental authorities and stakeholders to support acceptance and robustness

Expected Results

- More reliable and comprehensive prediction of environmental impacts associated with floating wind projects
- Improved ability to identify and address potential environmental risks at early project stages
- Enhanced consistency and transparency in environmental assessments supporting permitting and planning processes

Current TRL

	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
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Innovation Line
Fact Sheet

Lifecycle Stage: Design and construction

Area 4: Wind farm layout design and site planning

Subarea 4.3: Environment impact and ecosystem effect mitigation

4.3.2 Tools for simulating and monitoring interactions between floating wind infrastructure and marine ecosystems

Development and application of tools for simulating and monitoring interactions between floating wind infrastructure and marine ecosystems. These tools combine modelling approaches and monitoring technologies to analyse how floating platforms, mooring systems and dynamic cables interact with marine wildlife, habitats and ecosystem processes during project operation.

Technological Objective

To improve understanding and management of interactions between floating wind infrastructure and marine ecosystems by enabling predictive assessment and continuous monitoring of impacts on marine wildlife, habitats and ecosystem processes, supporting environmentally responsible project planning and operation.

Specific Actions

- Adaptation of existing ecological and wildlife interaction models to account for floating wind-specific infrastructure and operational characteristics
- Integration of simulation tools with monitoring technologies such as acoustic sensors, visual systems, environmental DNA techniques and biological observations to capture wildlife and habitat responses to floating wind infrastructure
- Development of approaches to link predicted interaction patterns with observed monitoring data to improve ecosystem interaction models and mitigation strategies

Validation and Trial Needs

- Application of simulation and monitoring tools to representative floating wind case studies
- Validation of model predictions through comparison with data collected from monitoring campaigns where available
- Evaluation of tool performance and usability in supporting environmental assessment and mitigation planning

Expected Results

- Improved ability to predict and observe interactions between floating wind infrastructure and marine ecosystems, including wildlife and habitat responses
- Reduced uncertainty in environmental impact assessments related to fauna-infrastructure interactions
- Enhanced basis for defining mitigation measures and operational adjustments where required

Current TRL

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Innovation Line
Fact Sheet

Lifecycle Stage: Design and construction

Area 4: Wind farm layout design and site planning

Subarea 4.3: Environment impact and ecosystem effect mitigation

4.3.3 Continuous environmental monitoring systems

Deployment and integration of continuous environmental monitoring systems for floating wind farms, enabling long-term observation of key environmental indicators during construction, operation and decommissioning phases. These include parameters such as underwater noise, seabed disturbance, biodiversity, habitat interactions and species identification through automated monitoring approaches, supporting environmental management, regulatory compliance and adaptive mitigation.

Technological Objective

To support effective environmental management of floating wind projects by enabling continuous, reliable and automated monitoring of environmental conditions and ecological indicators through interoperable and decision-ready data collection approaches throughout the project lifecycle.

Specific Actions

- Integration of existing environmental monitoring technologies into coherent, long-term monitoring systems suitable for offshore floating environments
- Definition of relevant environmental and ecological indicators, including underwater noise, seabed disturbance, species presence, habitat condition and biodiversity trends, aligned with regulatory and project needs
- Adaptation of monitoring systems to floating wind infrastructure, including power supply, data transmission and robustness under dynamic conditions
- Development of automated data integration and analysis approaches enabling continuous processing of environmental, acoustic and visual monitoring data into ecologically meaningful and reporting-ready outputs

Validation and Trial Needs

- Deployment of continuous monitoring systems in representative floating wind project environments
- Verification of system reliability, data quality and operational robustness over extended monitoring periods
- Assessment of data usability for regulatory reporting, environmental management and adaptive mitigation actions
- Comparative validation against conventional campaign-based monitoring approaches where relevant
- Validation of monitoring approaches to support regulatory acceptance and scalable replication across floating wind projects

Expected Results

- Reliable long-term environmental datasets supporting floating wind project operation, compliance and environmental assessment
- Reduced reliance on discontinuous or campaign-based monitoring approaches
- Improved ability to detect environmental changes and ecosystem interactions during project operation
- Improved comparability and usability of environmental monitoring outputs through standardised and interoperable ecological metrics

Current TRL

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Innovation Line
Fact Sheet

Lifecycle Stage: Design and construction

Area 4: Wind farm layout design and site planning

Subarea 4.3: Environment impact and ecosystem effect mitigation

4.3.4 Mitigation, compensation and eco-design measures for wind farm

Development and application of mitigation, compensation and eco-design measures for floating wind farms, aimed at reducing environmental impacts and supporting ecosystem resilience through informed design choices, layout decisions, operational strategies and nature-inclusive approaches across the project lifecycle.

Technological Objective

To minimise the environmental impact of floating wind projects by integrating mitigation, compensation, eco-design and adaptive environmental management principles into park design and planning, supporting lower environmental footprint and improved ecosystem resilience across the project lifecycle.

Specific Actions

- Identification of design and layout features that can reduce environmental impacts associated with floating wind infrastructure
- Assessment of eco-design solutions addressing key impact drivers such as seabed disturbance, underwater noise, habitat interaction and end-of-life environmental implications
- Evaluation of compensation measures applicable where mitigation at source is not feasible
- Assessment of nature-inclusive and ecosystem restoration approaches, supported by environmental monitoring and adaptive management strategies where relevant

Validation and Trial Needs

- Application of mitigation and eco-design measures to representative floating wind park design studies
- Assessment of the effectiveness of proposed measures through modelling, monitoring data or documented offshore experience
- Pilot validation and long-term monitoring of selected mitigation, eco-design or nature-inclusive measures under representative offshore conditions
- Review of proposed measures with environmental authorities and stakeholders to support acceptance and practical implementation

Expected Results

- Reduced environmental footprint of floating wind farms through design-driven mitigation measures
- Clear understanding of the effectiveness and limitations of mitigation, compensation and nature-inclusive approaches
- Improved integration of environmental considerations into floating wind park design and planning processes

Current TRL

	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Current TRL					

Innovation Line Fact Sheet

Lifecycle Stage: Design and construction

Area 4: Wind farm layout design and site planning

Subarea 4.3: Environment impact and ecosystem effect mitigation

4.3.5 Solutions to enable compatibility and co-activity between floating wind farms and fishing activities

Development and application of practical design, access and operational solutions to enable safe coexistence between floating wind farms and fishing activities. The focus is on reducing operational conflicts, improving navigation and access compatibility, and enabling fisheries-specific co-activity arrangements within floating wind farm areas.

Technological Objective

To improve coexistence between floating wind projects and fishing activities by identifying practical solutions that enhance navigation safety, access compatibility and operational coordination in shared maritime areas.

Specific Actions

- Assessment of technical and operational constraints affecting coexistence, including mooring layouts, exclusion zones and navigation safety
- Development of fisheries-specific design and operational approaches that facilitate safe access, navigation and co-activity, such as layout adaptations or dedicated transit corridors

Validation and Trial Needs

- Application of compatibility assessment tools to representative floating wind planning case studies involving fishing activities
- Review of existing offshore experience and pilot initiatives involving coexistence between wind farms and fishing activities
- Engagement with fishing stakeholders and authorities to assess feasibility, safety and acceptance of proposed solutions

Expected Results

- Improved understanding of realistic coexistence options between floating wind farms and fishing activities
- Reduced risk of operational conflicts and safety issues during project development and operation
- Better-informed planning decisions supporting socially acceptable deployment of floating wind projects

Current TRL

	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Current TRL					

Innovation Line
Fact Sheet

Lifecycle Stage: Design and construction

Area 4: Wind farm layout design and site planning

Subarea 4.3: Environment impact and ecosystem effect mitigation

4.3.6 Advanced solutions for cumulative impact assessment

Development of applied methodologies and decision-support tools to support project-level cumulative impact assessment for floating wind developments, using available regional environmental baselines, ecosystem sensitivities and relevant information on other marine activities. The line focuses on improving consistency, transparency and usability in the treatment of cumulative effects within planning, consenting and adaptive management processes.

Technological Objective

To improve the consistency and transparency of cumulative impact assessment for floating wind projects by providing practical tools and workflows that place project-related environmental effects in the context of existing environmental conditions and ecosystem sensitivities.

Specific Actions

- Develop practical cumulative assessment approaches that combine project-related pressures with available regional environmental baselines, ecosystem sensitivities and monitoring datasets
- Define standardised pressure–pathway–receptor frameworks to support consistent treatment of cumulative effects across projects and consenting processes
- Build decision-support workflows linking cumulative assessment outputs to mitigation, monitoring and adaptive management actions where relevant

Validation and Trial Needs

- Calibration and validation using regional monitoring datasets and historical baselines (species, habitats, fisheries, oceanographic drivers)
- Application to representative case studies to test sensitivity to scenarios, data gaps and model assumptions, and to benchmark against current planning and consenting practice
- Demonstration with stakeholder/regulator engagement to validate usability, transparency and traceability for consenting and maritime spatial planning

Expected Results

- Operational cumulative assessment tools supporting more consistent treatment of project-level cumulative effects within planning and consenting workflows
- More consistent, transparent and defensible consenting dossiers, reducing rework and dispute risk
- Improved mitigation and monitoring strategies aligned with cumulative pressures and ecosystem-level thresholds

Current TRL

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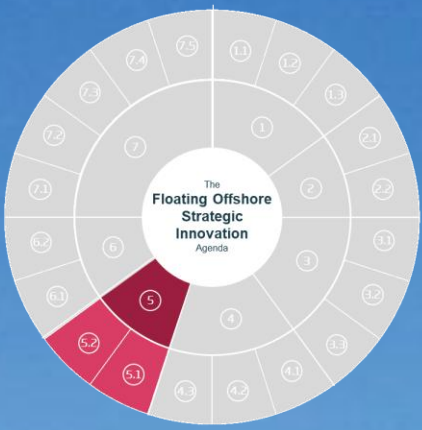

Area 5 - Industrialisation

Innovation Line
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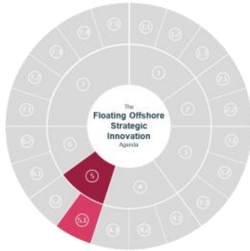

Lifecycle Stage: Industrialisation, logistics and offshore installation

Area 5: Industrialisation

Subarea 5.1: Modularisation, process-oriented standardisation and industrial automation

5.1.1 Modular architectures and process-oriented interface standardisation

Development and adoption of modular architectures and fit-for-purpose standardised interfaces for floating wind systems and subsystems, enabling easier integration, installation, maintenance and replacement of components. This line focuses on identifying and harmonising interface solutions where standardisation can deliver industrial benefits – such as reduced engineering effort, improved interoperability and repeatability – while preserving the flexibility needed to accommodate different floating concepts, suppliers and project-specific conditions.

Technological Objective

To accelerate floating wind industrialisation by enabling interoperable, repeatable and scalable system integration through the selective standardisation of key mechanical, electrical and functional interfaces.

Specific Actions

- Identification and prioritisation of interface types across floating wind systems and subsystems (e.g. mechanical connection points, electrical interfaces, auxiliary systems, monitoring and control interfaces, lifting and handling interfaces), including functional requirements and acceptable boundary conditions.
- Development of fit-for-purpose interface specifications, tolerances and verification approaches for selected interface categories with cross-concept and cross-supplier standardisation potential
- Assessment of standardisation and modularisation trade-offs (cost, weight, manufacturability, maintainability, logistics and performance) to identify where harmonisation supports industrial scalability without constraining design optimisation or innovation

Validation and Trial Needs

- Validation of proposed interface solutions through representative design studies, integration exercises and selected cross-supplier compatibility assessments
- Verification of interface robustness and performance through component-level testing and integration trials, where relevant
- Review and alignment with industry stakeholders and certification bodies to support acceptance, qualification and uptake

Expected Results

- Reduced project-specific engineering effort and improved integration efficiency across floating wind projects
- Improved compatibility and interchangeability of components, supporting faster installation and easier replacement
- Increased repeatability and scalability of floating wind industrial processes enabled by common interface solutions

Current TRL

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Innovation Line
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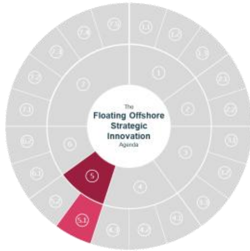

Lifecycle Stage: Industrialisation, logistics and offshore installation

Area 5: Industrialisation

Subarea 5.1: Modularisation, process-oriented standardisation and industrial automation

5.1.2 Industrialised, automated and repeatable manufacturing processes for floating wind components

Development and deployment of industrialised, automated and repeatable manufacturing processes for floating wind components and subassemblies, supporting the transition from prototype-based production to scalable industrial manufacturing. This includes adapting manufacturing technologies from other industries, incorporating design-for-manufacturing approaches and developing component designs compatible with automated and robotised production while ensuring consistent quality, fatigue performance, production efficiency and industrial viability.

Technological Objective

To enable scalable and cost-effective manufacturing of floating wind components by increasing industrialisation, automation and process repeatability across the supply chain, while integrating manufacturing-oriented design approaches that support reliable large-scale production and structural performance of floating wind systems.

Specific Actions

- •Identification of floating wind components and manufacturing steps with the highest potential for industrialisation, automation and robotisation, considering production scalability, fatigue-critical requirements and applicability across steel, composite and concrete structures
- Definition of quality control, traceability and process standardisation frameworks enabling repeatable, high-volume manufacturing across the floating wind supply chain
- Development and adaptation of automated and semi-automated manufacturing processes for floating wind components, including design-for-manufacturing approaches compatible with industrial production and process repeatability requirements
- Assessment of the techno-economic viability and industrial scalability of automated manufacturing routes, including trade-offs between capital investment, production speed, quality performance and manufacturability

Validation and Trial Needs

- Demonstration of industrialised and automated manufacturing processes through pilot production lines or representative manufacturing campaigns
- Verification of process repeatability, quality consistency and productivity gains compared to conventional manufacturing approaches
- Assessment of manufacturing process robustness under increased production rates and varying component configurations

Expected Results

- Increased production capacity, repeatability and industrial readiness for floating wind components
- Reduced manufacturing costs and improved production efficiency through automation and process repeatability
- Improved quality assurance, traceability and fatigue-oriented manufacturing consistency, including reduced defect rates, lower rework needs and improved compliance with manufacturing tolerances

Current TRL

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Innovation Line
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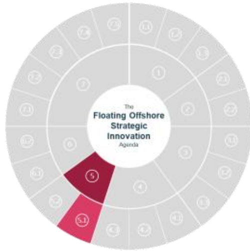

Lifecycle Stage: Industrialisation, logistics and offshore installation

Area 5: Industrialisation

Subarea 5.1: Modularisation, process-oriented standardisation and industrial automation

5.1.3 Industrialisable materials, protective systems and coatings for floating wind components

Selection, adaptation and qualification of materials, protective systems and coating solutions compatible with industrial-scale manufacturing and long-term operation of floating wind components. The focus is on scalable material solutions that enhance durability, reduce maintenance requirements and support circular design approaches and modular replacement strategies under harsh offshore conditions.

Technological Objective

To enable reliable and cost-effective industrial production of floating wind components by developing materials and protective systems that combine offshore durability, manufacturability, reduced maintenance requirements and compatibility with circular design and modular replacement strategies.

Specific Actions

- Identification and qualification of materials, protective systems and coatings suitable for floating wind components, ensuring offshore durability and compatibility with industrial manufacturing
- Assessment of the compatibility between selected materials and scalable manufacturing processes for floating wind components, supporting modular production approaches
- Characterisation of degradation mechanisms and lifecycle performance of materials and coatings under floating offshore conditions to support maintenance optimisation, component replacement and circular material use

Validation and Trial Needs

- Validation of materials and coatings through laboratory testing and exposure data from offshore or marine environments
- Review of operational experience from offshore wind, oil & gas and maritime sectors to support material selection
- Application of selected solutions in representative floating wind component designs to assess industrial suitability

Expected Results

- Improved durability and service life of floating wind components
- Reduced maintenance and lifecycle costs through appropriate material and coating selection
- Increased confidence in industrial-scale production using standardised and proven protection solutions

Current TRL

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Current TRL					

Innovation Line
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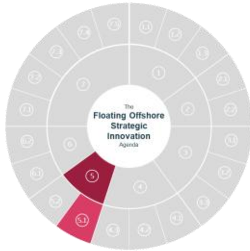

Lifecycle Stage: Industrialisation, logistics and offshore installation

Area 5: Industrialisation

Subarea 5.1: Modularisation, process-oriented standardisation and industrial automation

5.1.4 Assessment and strengthening of EU floating wind supply chain capabilities

Assessment and strengthening of European supply chain capabilities for floating wind, focusing on the identification of industrial capacities, knowledge gaps, bottlenecks and collaboration opportunities across key segments of the value chain such as manufacturing, assembly and logistics. The analysis considers the readiness and scalability of the European industrial ecosystem to support large-scale deployment of floating wind technologies, considering the evolving nature of the supply chain and the need for periodic updates.

Technological Objective

To support large-scale deployment of floating wind in Europe by improving the readiness, robustness and competitiveness of the European industrial supply chain through a better understanding of industrial capacities, capability gaps and opportunities for collaboration across the value chain.

Specific Actions

- Mapping of European industrial capabilities relevant to floating wind manufacturing, assembly and logistics across the supply chain
- Identification of critical bottlenecks, knowledge gaps and capacity constraints affecting large-scale deployment of floating wind
- Definition and monitoring of key performance indicators (e.g. production capacity, lead times, utilisation rates) to track supply chain readiness and evolution over time
- Assessment of collaboration opportunities and strategic actions to strengthen supply chain resilience, scalability and competitiveness, considering evolving market conditions

Validation and Trial Needs

- Application of supply chain assessment methodologies to representative floating wind deployment scenarios
- Comparison of identified capabilities and gaps with projected deployment volumes and timelines
- Engagement with industry stakeholders to validate findings, refine prioritised actions and support periodic updates of the assessment

Expected Results

- Clear and updated overview of European floating wind supply chain capabilities and limitations
- Identification of priority actions to support industrial scale-up and reduce deployment risks, supported by measurable indicators such as capacity, lead times and supply chain performance
- Improved alignment between industrial capacity development and floating wind deployment targets

Current TRL

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Innovation Line
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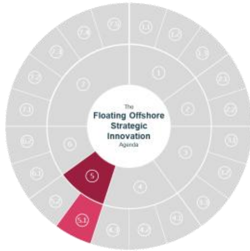

Lifecycle Stage: Industrialisation, logistics and offshore installation

Area 5: Industrialisation

Subarea 5.1: Modularisation, process-oriented standardisation and industrial automation

5.1.5 Standardisation boundaries and interoperability across floating wind platform designs

Development of frameworks and engineering guidelines to define where standardisation and interoperability are feasible across different floating foundation concepts, and where site-specific constraints impose limits. The line targets identification of “standardisable” subsystems and interfaces (tower–floater, mooring/fairleads, dynamic cable interfaces, auxiliaries, access systems), and the translation of boundary conditions (metocean, water depth, soils, port/installation constraints, certification) into clear design envelopes to support industrial-scale serialisation without compromising performance.

Technological Objective

To enable industrial-scale deployment by defining standardisation domains and interoperability rules across floater concepts, establishing practical design envelopes that maximise commonality while managing site-driven constraints.

Specific Actions

- Map and classify subsystems/interfaces with standardisation potential across concepts, defining functional requirements and minimum common specifications
- Quantify site-driven boundary conditions that limit standardisation (metocean classes, depth/soils, logistics/ports, installation methods, grid/interface constraints) and translate into design envelopes
- Develop interoperability guidelines, interface standards and configuration management rules to support product platforms and certification pathways

Validation and Trial Needs

- Application to multiple floater concepts and representative sites to demonstrate transferability of proposed standards and envelopes
- Benchmarking against existing industrial designs to quantify commonality gains, cost impacts and performance trade-offs
- Engagement/validation with OEMs, developers and certifiers to confirm acceptability, certification alignment and implementation feasibility

Expected Results

- Defined standardisation boundaries and design envelopes identifying what can be standardised vs site-specific
- Interface/interoperability specifications enabling modular product platforms and reduced redesign effort
- Improved industrialisation readiness through higher repeatability, simplified certification and supply-chain scalability

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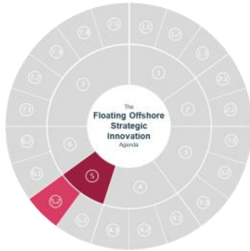

Lifecycle Stage: Industrialisation, logistics and offshore installation

Area 5: Industrialisation

Subarea 5.2: Port-based component integration and heavy lifting operations

5.2.1 System integration and advanced port-based assembly

Development and application of advanced system integration and port-based assembly approaches for floating wind components and subsystems. The focus is on maximising system integration in port environments to reduce offshore installation complexity, vessel requirements and weather dependency.

Technological Objective

To improve efficiency, safety and predictability of floating wind installation campaigns by shifting integration and assembly activities from offshore environments to controlled port-based facilities.

Specific Actions

- Identification of floating wind components and subsystems suitable for full or partial integration at port, considering spatial, lifting, transport and handling constraints
- Definition of industrialised port-based assembly sequences compatible with floating wind platform sizes and configurations
- Assessment of port facility requirements for advanced assembly and integration operations, including quay capacity, crane requirements, draft, laydown areas and load-out constraints
- Assessment of interfaces between integrated systems to ensure transportability, structural integrity, installation readiness and compatibility with port handling and load-out operations

Validation and Trial Needs

- Demonstration of port-based integration and assembly approaches through representative integration campaigns, pilot projects or trial assembly activities at suitable existing port facilities
- Verification of structural, stability and handling performance during transport and tow-out operations
- Assessment of installation efficiency gains and reduction of offshore work compared to conventional approaches

Expected Results

- Increased proportion of floating wind system integration completed in port
- Reduced offshore installation time, vessel dependency and weather exposure
- Improved installation reliability, safety and schedule predictability through better alignment between assembly strategies and port capabilities

Current TRL

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Innovation Line
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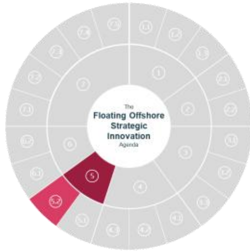

Lifecycle Stage: Industrialisation, logistics and offshore installation

Area 5: Industrialisation

Subarea 5.2: Port-based component integration and heavy lifting operations

5.2.2 Innovative port infrastructure solutions and design criteria to assess, adapt or develop port facilities capable of supporting floating wind hub and marshalling operations

Development and application of design criteria and infrastructure solutions to assess, adapt or develop port facilities capable of supporting floating wind hub and marshalling operations. The focus is on port configurations supporting assembly and system integration activities, including alternative infrastructure concepts such as floating port structures where conventional port surface is insufficient, while addressing requirements related to ground bearing capacity, quay strength, available space, draft constraints, wet and dry storage needs, scalability considerations and integration with installation and logistics strategies for large-scale deployment.

Technological Objective

To enable ports to effectively support large-scale floating wind deployment by defining clear technical criteria and infrastructure solutions aligned with floating wind assembly, integration and marshalling requirements, while enabling cost-efficient, scalable and repeatable industrial operations.
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Specific Actions

- Definition of technical requirements for ports supporting floating wind activities, including structural capacity, draft, spatial layout, logistics flows and throughput constraints
- Assessment of existing port infrastructure against floating wind requirements to identify adaptation needs and development options
- Development of design guidelines, planning methodologies and digital assessment tools to support port optimisation, bottleneck identification and investment decisions for floating wind hubs
- Integration of port design approaches with installation, towing and offshore logistics strategies to improve compatibility with large-scale deployment operations

Validation and Trial Needs

- Application of port assessment and design criteria to representative European ports under large-scale floating wind deployment scenarios
- Evaluation of infrastructure solutions through feasibility studies, logistics simulations and implementation of selected port upgrades where available
- Validation of integration between port operations, installation strategies and towing/logistics workflows under representative operational scenarios
- Review of outcomes with port authorities, developers and industrial stakeholders to validate applicability and robustness

Expected Results

- Clear and consistent criteria for assessing port readiness for floating wind activities
- Improved alignment between floating wind industrial needs and port infrastructure capabilities
- Increased deployment capacity and reduced logistical bottlenecks for large-scale floating wind operations
- More efficient planning and investment decisions for port adaptation and development supporting floating wind hubs

Current TRL

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Innovation Line
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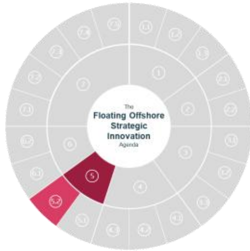

Lifecycle Stage: Industrialisation, logistics and offshore installation

Area 5: Industrialisation

Subarea 5.2: Port-based component integration and heavy lifting operations

5.2.3 Innovative specialised and hybrid vessel solutions supporting installation, towing and decommissioning operations for floating wind systems

Development and adaptation of specialised and hybrid vessel concepts for floating wind installation, towing and decommissioning operations, addressing lifting constraints associated with large turbine components and improving operational flexibility for next-generation floating wind systems.

Technological Objective

To improve the efficiency, safety and predictability of floating wind installation and removal operations by developing specialised and hybrid vessel solutions adapted to large turbine components, towing operations and floating wind system requirements.

Specific Actions

- Identification of installation, towing and decommissioning operations that define vessel capability requirements for floating wind systems
- Assessment of existing vessel fleets and identification of capability gaps related to lifting capacity, crane outreach, deck space and station-keeping requirements for floating wind operations
- Development and evaluation of innovative and hybrid vessel concepts adapted to next-generation turbine sizes and floating wind installation strategies

Validation and Trial Needs

- Demonstration of adapted or specialised vessels in representative floating wind installation or removal campaigns
- Assessment of operational performance, safety and weather sensitivity compared to conventional vessel approaches
- Review of vessel utilisation efficiency and availability across multiple floating wind projects

Expected Results

- Improved suitability of vessel fleets for floating wind installation and removal operations
- Reduced installation and decommissioning risk and weather-related delays
- Increased operational flexibility and predictability for floating wind project execution

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Innovation Line
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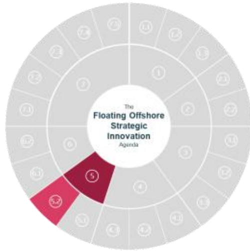

Lifecycle Stage: Industrialisation, logistics and offshore installation

Area 5: Industrialisation

Subarea 5.2: Port-based component integration and heavy lifting operations

5.2.4 Digital tools for planning and operational execution of port activities

Development and application of digital tools to support planning, coordination and operational execution of port activities related to floating wind projects. These tools enable improved scheduling, heavy lifting planning, component logistics management, assembly sequencing and operational optimisation for port-based integration and marshalling operations.

Technological Objective

To improve efficiency, predictability and coordination of port operations supporting floating wind projects by enabling data-driven planning and real-time operational decision-making.

Specific Actions

- Adaptation of existing port and logistics digital tools to floating wind assembly and marshalling operations, enabling coordinated planning of heavy lifting activities, component logistics and assembly sequencing in port environments
- Integration of scheduling, resource management and risk assessment functions into unified digital planning environments
- Development of interfaces to support coordination between port operators, developers, vessel operators and contractors

Validation and Trial Needs

- Application of digital planning and operational tools to representative floating wind port operations and integration campaigns
- Verification of improvements in scheduling accuracy, resource utilisation and operational robustness compared to conventional planning approaches
- Assessment of usability and decision-support value through feedback from port operators and project teams

Expected Results

- Improved planning and execution of port-based floating wind activities
- Reduced delays and inefficiencies driven by poor coordination or reactive decision-making
- Enhanced transparency and predictability of port operations supporting floating wind deployment

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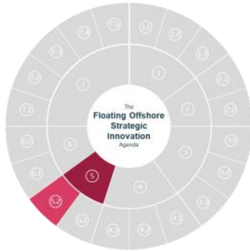
Innovation Line Fact Sheet



Lifecycle Stage: Industrialisation, logistics and offshore installation

Area 5: Industrialisation

Subarea 5.2: Port-based component integration and heavy lifting operations

5.2.5 AI- digital twin-based monitoring systems for port operations, asset tracking and safety management during floating wind assembly and integration

Development and deployment of AI-enabled monitoring and digital twin systems to improve port-side assembly, integration and heavy lifting operations for floating wind. The line targets real-time visibility of assets, equipment and workfront status (components, cranes, transporters, quayside constraints), together with predictive safety and risk management during complex lifts and concurrent operations, enabling higher throughput and reduced incidents.

Technological Objective

To increase port integration capacity, schedule reliability and safety by implementing digital twin + AI solutions that provide real-time situational awareness, predictive risk alerts and decision support for heavy lifting and assembly operations.

Specific Actions

- Develop port operation digital twins integrating layout, equipment capacity, constraints and real-time data streams (IoT, GPS/RFID, vision, crane telemetry)
- Implement AI models for asset tracking, congestion detection, lift-path monitoring and anomaly/risk prediction (exclusion zones, near-miss patterns)
- Define data standards, interfaces and cybersecurity requirements to connect digital tools with port TOS, HSE systems and contractor workflows

Validation and Trial Needs

- Pilot deployment in an operational port environment to validate tracking accuracy, latency and robustness under marine/industrial conditions
- Demonstration of safety use-cases (automated exclusion zones, lift monitoring, near-miss detection) and benchmarking vs baseline HSE performance
- Verification of operational KPIs (turnaround time, crane utilisation, rework reduction) and user adoption across multiple contractors

Expected Results

- Real-time port operational visibility (assets, workfront status, equipment utilisation) supporting higher throughput
- Improved safety performance via predictive alerts, better situational awareness and reduced human-error exposure during lifts
- Reduced delays and integration cost through optimised sequencing, fewer conflicts and data-driven decision-making

Current TRL

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Area 6 - Logistics and offshore installation

Innovation Line Fact Sheet

Lifecycle Stage: Industrialisation, logistics and offshore installation

Area 6: Logistics and offshore installation

Subarea 6.1: Logistics, load-out, float-off, wet storage and port-to-site transport

6.1.1 Industrialised load-out and float-on/float-off solutions in port environments

Development and industrialisation of load-out and float-on/float-off solutions for floating wind platforms and integrated modules in port environments. These solutions aim to establish repeatable, safe and efficient methodologies for transferring large floating structures from fabrication or assembly areas to water, supporting modular integration zones in ports and reducing operational risk, weather dependency and reliance on project-specific equipment.

Technological Objective

To improve safety, efficiency and scalability of floating wind deployment by standardising and industrialising load-out and float-on/float-off operations in port environments, enabling modular assembly and repeatable transfer of large floating wind modules to water.

Specific Actions

- Identification of load-out and float-on/float-off methodologies suitable for different floating platform typologies and port configurations
- Definition of repeatable operational sequences, structural checks and stability criteria enabling safe transfer of large floating wind modules to water
- Assessment of load distribution, structural reinforcement needs and temporary support systems required during load-out and float-on/float-off operations
- Assessment of workability limits and weather-related operational risks associated with identified load-out and float-on/float-off methodologies, considering port-specific environmental conditions such as tides, wind and wave exposure
- Evaluation of integration opportunities and operational synergies with other marine logistics activities, including transport strategies and pre- or post-load-out WTG integration approaches

Validation and Trial Needs

- Demonstration of industrialised load-out and float-on/float-off procedures in representative floating wind integration campaigns
- Verification of structural integrity, stability margins and operational safety during transfer operations
- Evaluation of time efficiency and risk reduction compared with project-specific or ad hoc load-out approaches

Expected Results

- Increased repeatability and predictability of load-out and float-on/float-off operations
- Reduced operational risk and weather sensitivity during port-based deployment phases
- Improved scalability of floating wind industrial campaigns through standardised and reusable port integration solutions

Current TRL

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Innovation Line Fact Sheet

Lifecycle Stage: Industrialisation, logistics and offshore installation

Area 6: Logistics and offshore installation

Subarea 6.1: Logistics, load-out, float-off, wet storage and port-to-site transport

6.1.2 Mature wet-storage solutions and temporary management of floating assets

Development and application of mature wet-storage solutions and associated procedures for temporary management of floating wind assets during fabrication, integration, tow-out, installation and maintenance phases. This includes optimisation of temporary mooring strategies, storage configurations, monitoring approaches and operational planning adapted to project execution schedules, port layouts, sheltered-water opportunities and location-specific environmental and operability constraints.

Technological Objective

To enable reliable and scalable wet-storage operations for floating wind assets by optimising temporary mooring strategies, storage configurations, operational planning and monitoring procedures under varying project execution schedules, port layouts and environmental conditions.

Specific Actions

- Definition of wet-storage configurations, temporary mooring strategies and storage requirements for floating wind platforms under representative harbour and nearshore conditions, considering asset configurations, storage durations and project execution schedules
- Development of monitoring and inspection approaches to ensure asset integrity, stability and operational readiness during temporary storage periods
- Assessment of operational procedures for asset handling, access planning, safety management and contingency response during wet-storage operations
- Assessment of environmental constraints, regulatory requirements and port infrastructure needs associated with wet-storage deployment and temporary floating asset management

Validation and Trial Needs

- Demonstration of wet-storage procedures through representative floating wind port operations or pilot projects
- Verification of mooring performance, asset integrity and monitoring effectiveness during extended storage periods
- Evaluation of operational reliability under varying environmental conditions, port layouts and sheltered-water constraints
- Validation of compatibility between wet-storage strategies and project execution schedule requirements, including environmental and regulatory compliance aspects

Expected Results

- Safer and more predictable wet-storage operations for floating wind platforms
- Reduced risk of asset damage, drift or loss of availability during temporary storage phases
- Improved logistics flexibility and compatibility with industrial-scale deployment and installation schedules
- Increased confidence in wet-storage solutions under varying port, environmental and regulatory conditions

Current TRL

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Innovation Line
Fact Sheet

Lifecycle Stage: Industrialisation, logistics and offshore installation

Area 6: Logistics and offshore installation

Subarea 6.1: Logistics, load-out, float-off, wet storage and port-to-site transport

6.1.3 Floating transport and optimised towing strategies

Development and optimisation of floating transport and towing strategies for floating wind assets, including wet-tow and floating transport operations during pre-service, integration and deployment phases. The line focuses on logistics approaches that improve tow-out and tow-back operations through optimised routing, operational planning and tug configurations, enabling safe, cost-efficient transport and supporting industrialised multi-unit deployment campaigns under site-specific metocean conditions.

Technological Objective

To increase the safety, reliability and efficiency of floating asset transport operations by applying optimised towing strategies, logistics planning and vessel coordination adapted to environmental conditions, operational constraints and project execution schedules.

Specific Actions

- Definition of towing strategies and operational limits considering platform hydrodynamic behaviour, stability, transport configuration and metocean constraints
- Development of planning approaches for route optimisation, towing timing and tug selection / configuration for representative floating wind transport scenarios
- Assessment of hull adaptations, towing interfaces and access arrangements to improve transport efficiency and operational robustness
- Assessment of contingency procedures, vessel availability and risk mitigation strategies supporting safe and efficient towing operations during large-scale deployment campaigns

Validation and Trial Needs

- Validation of towing strategies through representative transport case studies and operational simulations
- Review of towing performance and operational outcomes from pilot or pre-commercial floating wind projects where available
- Verification of operability assumptions and risk controls against recorded metocean data and observed towing conditions
- Assessment of transport strategy compatibility with vessel market availability and representative project execution schedule assumptions

Expected Results

- Improved operability and reduced weather-related delays during towing operations
- Increased safety margins and clearer operational limits for floating asset transport
- Improved logistics planning and transport flexibility under representative deployment conditions
- More predictable and cost-efficient transport operations supporting industrial-scale floating wind deployment

Current TRL

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Innovation Line Fact Sheet

Lifecycle Stage: Industrialisation, logistics and offshore installation

Area 6: Logistics and offshore installation

Subarea 6.1: Logistics, load-out, float-off, wet storage and port-to-site transport

6.1.4 Industrialised methodologies for handling and loading dynamic power cables and accessories

Development and industrialisation of methodologies for handling, loading, storage and deployment preparation of dynamic power cables used in floating wind projects. This line focuses on improving the safety, reliability and repeatability of cable logistics operations while reducing damage risk and enabling efficient port-to-installation cable handling workflows at industrial deployment scale.

Technological Objective

To increase the reliability, safety and scalability of dynamic cable logistics by implementing standardised and industrialised handling, storage and loading procedures compatible with large-scale floating wind deployment.

Specific Actions

- Identification of critical handling steps and risk factors associated with dynamic cable transport, storage and loading operations
- Development of standardised procedures, equipment configurations and inspection protocols for cable storage, handling and loading activities
- Assessment of cable bending limits, tension control and protection requirements during port-based logistics and pre-installation handling phases

Validation and Trial Needs

- Demonstration of industrialised cable handling procedures during representative port logistics or installation preparation campaigns
- Verification of cable integrity and mechanical performance following handling and loading operations
- Evaluation of operational efficiency gains and reduction of damage incidents compared with non-standardised approaches

Expected Results

- Reduced risk of mechanical damage to dynamic cables during logistics and pre-installation phases
- Increased repeatability and predictability of cable handling operations
- Improved readiness and reliability of dynamic cables prior to offshore installation

Current TRL

	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Current TRL					

Innovation Line
Fact Sheet

Lifecycle Stage: Industrialisation, logistics and offshore installation

Area 6: Logistics and offshore installation

Subarea 6.1: Logistics, load-out, float-off, wet storage and port-to-site transport

6.1.5 Dry transport and internal logistics solutions for large-scale floating wind components within and between fabrication, assembly, storage and port facilities

Development and optimisation of onshore transport and internal logistics solutions for large-scale floating wind components within and between fabrication yards, assembly facilities, storage areas and port infrastructures. The line addresses the limited compatibility between current component designs and industrial transport chains, focusing on improving safety, efficiency and scalability of oversized component transport and handling operations.

Technological Objective

To develop and optimise integrated onshore transport and handling solutions for large-scale floating wind components by improving compatibility between component design, transport infrastructure and logistics systems, thereby increasing safety, efficiency and scalability.

Specific Actions

- Assessment and optimisation of transport corridors and supporting infrastructure (roads, bridges, marshalling areas and port interfaces) for oversized component movements, including bottleneck identification and upgrade needs
- Assessment of component design features, modularisation strategies and transport constraints to improve compatibility with industrial transport chains and logistics infrastructure
- Development of standardised handling methodologies and equipment configurations enabling safe and efficient onshore and yard transport of large-scale floating wind components
- Evaluation of coordination and operational interfaces between fabrication yards, storage areas, transport systems and port integration facilities to support scalable industrial deployment of floating wind components

Validation and Trial Needs

- Demonstration of optimised onshore transport and logistics solutions in representative industrial environments handling large-scale floating wind components
- Evaluation of coordination between fabrication, storage and integration phases under increased production volumes and industrial deployment scenarios
- Verification of operational safety, handling efficiency and infrastructure compatibility for oversized component transport and yard operations
- Assessment of transport corridor readiness and operational constraints under representative oversized component logistics conditions, including bottleneck identification and infrastructure limitations

Expected Results

- Validated and standardised logistics and handling solutions applicable across multiple industrial contexts
- Enhanced readiness of transport corridors, fabrication yards and port interfaces to support oversized floating wind component logistics
- Improved cost-efficiency and reduced logistical complexity for large-scale floating wind deployment
- Increased compatibility between component design, industrial transport systems and large-scale deployment requirements for floating wind projects

Current TRL

	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Current TRL					

Innovation Line
Fact Sheet

Lifecycle Stage: Industrialisation, logistics and offshore installation

Area 6: Logistics and offshore installation

Subarea 6.2: Offshore installation and hook-up of platforms, cables and mooring systems

6.2.1 Efficient offshore installation architectures, sequences, procedures and tools to increase operability for the complete system

Development and optimisation of offshore installation architectures, operational sequences, procedures and supporting tools for the complete floating wind system, including platforms, mooring systems and dynamic cables. This line aims to increase operability, reduce offshore time and improve coordination of multi-asset installation campaigns.

Technological Objective

To enhance safety, efficiency and predictability of offshore installation operations by defining optimised architectures, sequences and tools adapted to floating wind system characteristics.

Specific Actions

- Analysis and optimisation of installation sequences for floating platforms, mooring systems and dynamic cables
- Development of procedures and operational limits to increase weather operability and reduce offshore exposure time
- Assessment of installation tool requirements and compatibility with floating wind system interfaces

Validation and Trial Needs

- Application of optimised installation architectures to representative floating wind deployment scenarios
- Verification of operability improvements through simulation, operational analysis or pilot installation campaigns
- Comparison of optimised procedures with conventional offshore approaches in terms of time, risk and vessel utilisation

Expected Results

- Reduced offshore installation time and improved schedule predictability
- Increased weather operability and operational flexibility
- Improved coordination and efficiency of multi-unit installation campaigns

Current TRL

	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Current TRL					

Innovation Line
Fact Sheet

Lifecycle Stage: Industrialisation, logistics and offshore installation

Area 6: Logistics and offshore installation

Subarea 6.2: Offshore installation and hook-up of platforms, cables and mooring systems

6.2.2 In-situ positioning, balancing connection, and verification technologies

Development and deployment of advanced in-situ positioning, connection balancing and verification technologies for floating wind installation operations. These solutions integrate high-precision positioning systems, advanced sensing and automation tools to support accurate alignment, controlled connection and real-time validation of platforms, mooring systems and dynamic cables, while considering installation-driven design constraints and operability requirements.

Technological Objective

To improve the accuracy, safety and efficiency of offshore installation and hook-up operations by integrating advanced positioning, sensing, automation and verification technologies adapted to floating wind environments.

Specific Actions

- Assessment of positioning accuracy requirements for floating platform alignment, mooring connection balancing and dynamic cable hook-up operations across representative floating wind configurations
- Integration of advanced sensing, monitoring and automation systems into offshore installation workflows
- Evaluation of trade-offs between mooring/IAC design configurations, installation efficiency, operational workability and risk reduction objectives
- Development of verification protocols to confirm correct connection, tensioning and system readiness in real time

Validation and Trial Needs

- Demonstration of in-situ positioning and verification technologies during representative floating wind installation campaigns
- Verification of alignment precision, connection reliability and data accuracy under real offshore conditions
- Assessment of how installation experience and operational constraints can be translated into design requirements and optimisation criteria for mooring and inter-array cable systems
- Evaluation of operational efficiency improvements compared to conventional positioning and manual verification approaches

Expected Results

- Increased precision and reduced error rates during offshore positioning and connection operations
- Improved safety through enhanced real-time monitoring and verification
- Reduced need for corrective interventions and associated delays offshore

Current TRL

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Current TRL	□	■	□	□	□

Innovation Line
Fact Sheet

Lifecycle Stage: Industrialisation, logistics and offshore installation

Area 6: Logistics and offshore installation

Subarea 6.2: Offshore installation and hook-up of platforms, cables and mooring systems

6.2.3 Accelerated procedures and SIMOPS for multi-unit installation

Development and optimisation of accelerated offshore installation procedures and SIMOPS (simultaneous operations) strategies to enable efficient sequential or partially parallel installation of multiple floating wind units. These approaches improve coordination of vessels, assets and installation activities, reducing campaign duration and increasing operational efficiency at wind farm scale.

Technological Objective

To reduce installation timelines and offshore exposure by enabling safe and efficient simultaneous or partially parallel installation of floating wind platforms and associated systems through coordinated multi-vessel operations.

Specific Actions

- Definition of optimised installation sequences enabling sequential or partially parallel operations while maintaining safe operational limits
- Identification of operational interfaces, safety constraints and risk management strategies associated with SIMOPS in floating wind environments
- Development of coordination frameworks and decision-support tools for planning multi-vessel and multi-asset installation campaigns

Validation and Trial Needs

- Application of accelerated and SIMOPS-based installation procedures to representative floating wind installation scenarios
- Assessment of safety performance, coordination efficiency and time savings compared with conventional sequential installation approaches, including evaluation under realistic seasonal weather downtime conditions
- Verification of risk mitigation measures and schedule robustness under simulated or real offshore operational conditions using representative metocean and weather-window datasets

Expected Results

- Reduced total installation campaign duration for floating wind farms
- Improved vessel utilisation and offshore operational efficiency
- Increased confidence in the safe execution of multi-unit offshore installation campaigns

Current TRL

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Current TRL					

Innovation Line
Fact Sheet

Lifecycle Stage: Industrialisation, logistics and offshore installation

Area 6: Logistics and offshore installation

Subarea 6.2: Offshore installation and hook-up of platforms, cables and mooring systems

6.2.4 Highly automated hook-up equipment and procedures ideally standardised

Development and deployment of highly automated equipment and standardised procedures for offshore hook-up operations, including mooring line connection, dynamic cable connection and associated mechanical and electrical interfaces. These solutions aim to reduce manual intervention, increase safety and enable repeatable and standardised offshore connection activities across floating wind projects while improving operational workability under offshore conditions.

Technological Objective

To enhance the safety, efficiency and repeatability of offshore hook-up operations by introducing automated equipment, remote-assisted procedures and standardised connection methods adapted to floating wind systems.

Specific Actions

- Identification of hook-up operations with high manual workload, safety exposure or variability that could benefit from automation and procedural standardisation
- Development and integration of automated or remotely operated connection tools and monitoring systems
- Assessment of workability limits, weather operability impacts and mechanical downtime risks associated with automated hook-up systems compared with baseline procedures
- Definition of standardised operational procedures and interface requirements enabling repeatable hook-up operations across floating wind installations

Validation and Trial Needs

- Demonstration of automated hook-up equipment in representative offshore installation campaigns or controlled offshore trials
- Verification of connection reliability, tension control, positional accuracy and alignment under realistic metocean conditions
- Assessment of safety improvements, personnel-on-board reduction, operational robustness and weather-related operability impacts compared with conventional manual procedures

Expected Results

- Reduced manual intervention and offshore personnel exposure during hook-up operations
- Increased repeatability, precision and reliability of connection activities
- Potential reduction of installation costs at wind-farm scale through standardised and automated hook-up procedures
- Potential reduction of installation costs at wind-farm scale through standardised and automated hook-up procedures

Current TRL

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Current TRL	■	■	□	□	□

Innovation Line
Fact Sheet

Lifecycle Stage: Industrialisation, logistics and offshore installation

Area 6: Logistics and offshore installation

Subarea 6.2: Offshore installation and hook-up of platforms, cables and mooring systems

6.2.5 Geotechnical characterisation oriented to the execution of FOW anchoring systems

Geotechnical characterisation approaches specifically oriented to the execution of floating offshore wind anchoring systems, addressing the gap between current site characterisation practices and the requirements of scalable anchoring installation. This includes improving geophysical interpretation, reducing anchor positioning uncertainty and optimising site investigation strategies to minimise the need for repeated borehole campaigns while supporting reliable offshore execution.

Technological Objective

To improve the reliability, efficiency and predictability of anchoring system installation by aligning geotechnical investigation, geophysical interpretation and site investigation strategies with installation requirements and offshore execution constraints.

Specific Actions

- Definition of geotechnical data requirements and investigation scopes tailored to anchoring system design, positioning accuracy and installation methods
- Development of improved interpretation methodologies linking geophysical survey results, soil properties and anchor installation behaviour
- Integration of geotechnical deliverables into installation planning workflows to reduce positioning uncertainty and avoid repeated borehole campaigns

Validation and Trial Needs

- Application of execution-oriented geotechnical methodologies to representative floating wind anchoring projects
- Comparison of predicted installation behaviour with observed offshore anchoring performance and positioning accuracy
- Review of geotechnical deliverables with installers and contractors to confirm usability, reliability and decision-support value

Expected Results

- Reduced installation uncertainty and fewer offshore surprises during anchoring operations
- Improved alignment between anchor design assumptions, geophysical interpretation and execution realities
- More efficient and predictable anchoring installation campaigns with reduced need for repeated site investigation campaigns

Current TRL

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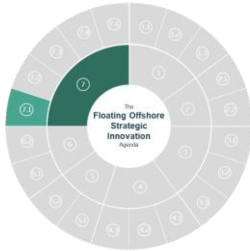
Current TRL					

Area 7 - Operation & Maintenance and Decommissioning

Innovation Line
Fact Sheet



Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.1: Data acquisition for O&M digitalisation

7.1.1 Advanced structural and condition monitoring of critical equipment and components using physical sensing and model-based approaches

Development and deployment of advanced monitoring systems for the structural and operational condition of critical floating wind assets, combining physical sensing technologies with model-based monitoring approaches to capture degradation mechanisms, abnormal behaviour, operational loads and structural responses under representative environmental and operational conditions.

Technological Objective

To enable earlier detection of failures, more accurate condition assessment and improved O&M planning by integrating advanced sensing technologies, metocean data and model-based monitoring approaches into floating wind farm operations.

Specific Actions

- Development of advanced sensing systems for continuous monitoring of structural loads, fatigue behaviour, degradation mechanisms and operational performance of floating wind components under representative environmental conditions
- Integration of physics-informed and model-based monitoring approaches with advanced signal processing methods and metocean data to distinguish degradation mechanisms from floating-specific operational variability
- Development of diagnostic and prognostic methodologies linking monitoring data with asset condition assessment, remaining useful life estimation and predictive maintenance strategies, including scalable inspection and monitoring approaches where relevant

Validation and Trial Needs

- Validation of monitoring system performance through representative experimental data, controlled testing environments, numerical reference cases and operational project data where available
- Verification of detection capability for relevant degradation mechanisms through controlled tests, historical failure data or correlated inspection findings
- Evaluation of system reliability, false-alarm rate, robustness and long-term stability under representative offshore conditions
- Validation under varying metocean and operational conditions, including seasonal variability, transient events and long-term degradation processes
- Comparison of monitoring outputs with conventional inspection and maintenance practices to assess added value, reliability and operational relevance

Expected Results

- Earlier detection of degradation and abnormal behaviour, reducing unplanned downtime and failure risk
- Improved, data-driven maintenance planning and reduced reliance on reactive interventions
- Increased confidence in asset condition assessment, supporting more efficient O&M strategies and reducing lifecycle costs

Current TRL

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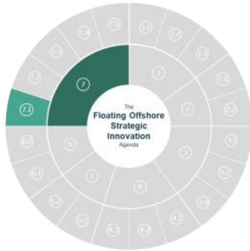
Current TRL					

Innovation Line
Fact Sheet



Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.1: Data acquisition for O&M digitalisation

7.1.2 Autonomous aerial and ground-based inspection systems for above-water assets

Deployment of autonomous aerial and robotic inspection systems for above-water and air-sea transition zone components of floating wind assets, supporting inspection activities across installation, commissioning and operational phases. These systems enable automated inspections, onboard defect detection and recurrent asset assessment while reducing offshore personnel exposure and improving inspection efficiency and data quality.

Technological Objective

To enhance the efficiency, safety and cost-effectiveness of inspection activities for floating wind farms by integrating autonomous and remotely operated inspection systems into floating wind inspection and asset management workflows.

Specific Actions

- Adaptation of aerial and robotic inspection systems to floating-specific motion and environmental conditions, including inspection activities around the air-sea transition zone and offshore structures
- Development of inspection protocols, data acquisition standards and repeatable inspection methodologies tailored to floating wind components and offshore operational conditions
- Integration of inspection outputs into digital asset management and maintenance decision systems, supporting remote operations and predictive maintenance workflows
- Assessment of long-range and persistent autonomous inspection capabilities to support reduced vessel dependency and increased inspection coverage in offshore wind farms

Validation and Trial Needs

- Pilot deployment of autonomous aerial and robotic inspection systems on operating floating wind assets under representative offshore conditions
- Verification of inspection performance, navigation stability and defect detection capability under representative offshore and air-sea transition zone conditions
- Evaluation of operational reliability, data acquisition quality and repeatability during extended inspection campaigns under varying metocean conditions

Expected Results

- Increased inspection frequency, flexibility and consistency without increasing operational risk
- Reduced need for manual offshore inspection campaigns
- Improved traceability, repeatability and quality of inspection data supporting predictive maintenance and asset integrity management
- Enhanced operational efficiency and reduced vessel dependency through autonomous and remotely operated inspection systems

Current TRL

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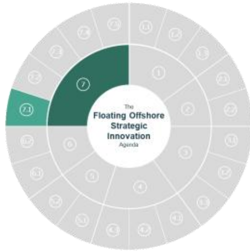
Current TRL					

Innovation Line
Fact Sheet



Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.1: Data acquisition for O&M digitalisation

7.1.3 Autonomous subsea inspection systems for floating infrastructures

Development of autonomous subsea inspection systems for floating wind infrastructures using ROV and AUV platforms equipped with advanced sensor payloads and supported by autonomous surface vehicles. These systems enable efficient and repeatable inspection and cleaning of moorings, anchors, dynamic cables and other submerged structural components, reducing vessel dependency, offshore personnel exposure and operational costs.

Technological Objective

To improve the safety, efficiency, reliability and cost-effectiveness of subsea inspections in floating wind farms by deploying autonomous underwater inspection systems capable of performing detailed inspections with minimal vessel support.

Specific Actions

- Development of autonomous subsea inspection systems using ROV and AUV platforms adapted to floating wind infrastructures
- Development of advanced sensor payloads, inspection methodologies and biofouling assessment approaches for detecting degradation in moorings, anchors, dynamic cables and submerged structures
- Development of cleaning and maintenance support tools for submerged structures, mooring systems and dynamic cables compatible with autonomous inspection platforms
- Integration of autonomous surface support platforms and operational workflows to improve inspection efficiency and reduce vessel dependency

Validation and Trial Needs

- Real-site offshore trials in representative floating wind assets to validate autonomous navigation, inspection stability and data acquisition performance
- Verification of inspection accuracy and defect detection capability compared with diver-based or vessel-based inspection methods
- Assessment of operational efficiency, inspection coverage and reduced vessel dependency enabled by autonomous inspection campaigns

Expected Results

- Increased inspection frequency and consistency across floating wind assets
- Earlier detection of degradation and biofouling in moorings, anchors and dynamic cables
- Reduced vessel dependency, lower offshore personnel exposure and improved cost-efficiency for subsea monitoring operations

Current TRL

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Current TRL					

Innovation Line
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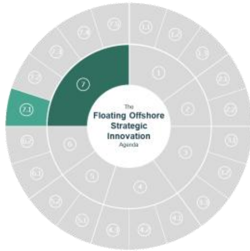

Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.1: Data acquisition for O&M digitalisation

7.1.4 Autonomous sensing and monitoring networks for floating wind environments

Development of autonomous sensing and monitoring networks for floating wind environments that combine robust sensor technologies with energy harvesting solutions and low-power underwater communication systems. These networks enable continuous monitoring of structural loads, fatigue behaviour, corrosion processes and environmental conditions across floating wind assets, including moorings, dynamic cables and submerged structures, while ensuring reliable data acquisition under harsh offshore conditions.

Technological Objective

To enable long-term, low-maintenance monitoring of floating wind assets by integrating durable sensing technologies with autonomous power supply and reliable underwater communication systems capable of operating in dynamic offshore environments.

Specific Actions

- Identification of critical sensing requirements and measurement points across floating wind systems, including moorings, dynamic cables and substructures.
- Development of robust sensing technologies for long-term monitoring of loads, fatigue and degradation in harsh offshore environments
- Development of autonomous sensing networks integrating energy harvesting and low-power underwater communication technologies

Validation and Trial Needs

- Laboratory and offshore testing of sensing technologies to verify long-term performance under representative dynamic loads, corrosion exposure and environmental conditions
- Field validation of autonomous sensing networks deployed on floating wind assets, including moorings, dynamic cables and submerged structural components
- Verification of reliable underwater communication, including wireless subsea transmission, together with energy autonomy and data integrity during long-term operation in realistic offshore environments

Expected Results

- Reliable and continuous monitoring of structural loads, degradation mechanisms and environmental conditions across floating wind assets
- Reduced dependence on wired power and communication systems for subsea monitoring applications
- Improved robustness and resilience of offshore sensing systems, enabling more efficient inspection, maintenance planning and asset integrity management

Current TRL

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Current TRL					

Innovation Line
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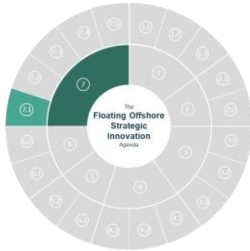

Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.1: Data acquisition for O&M digitalisation

7.1.5 Improvement of dynamic cable design and technical definition processes

Integration of operational and in-service performance data into dynamic cable design and specification processes for floating wind applications. The focus is on improving design accuracy, reducing uncertainty in cable behaviour and fatigue assessment, and ensuring that cable configurations are optimised for real operating conditions through the use of validated operational datasets.

Technological Objective

To develop more reliable operational-data-informed design methodologies for dynamic cables that enhance lifetime prediction, improve prediction of cable response under real operating conditions, reduce risk of failure, and support more efficient O&M planning.

Specific Actions

- Identification of key operational parameters influencing dynamic cable performance (motions, bending cycles, tension, temperature, soil-cable interaction, marine growth characteristics, thickness and weight per metre)
- Use of operational feedback, monitoring outputs and available in-service performance evidence to refine predictions of curvature variations, touchdown behaviour and global cable response under representative offshore conditions
- Improvement and adaptation of existing modelling tools and workflows through integration of operational datasets, advanced modelling options and user-defined cable properties
- Creation of design guidelines and modelling recommendations adapted to floating wind-specific dynamic behaviour conditions

Validation and Trial Needs

- Collection, recovery and analysis of operational data from existing dynamic cable installations under representative environmental and operational conditions
- Application of data-informed design improvements to new dynamic cable projects and comparison with legacy designs
- Verification of improved performance or reduced degradation through monitored operational periods
- Engagement with certification bodies and suppliers to validate revised specification frameworks

Expected Results

- More accurate and reliable dynamic cable designs with reduced uncertainty
- Better alignment between design assumptions and real operational cable behaviour
- Lower failure risk and reduced O&M costs associated with cable issues

Current TRL

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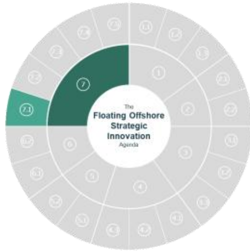
Current TRL					

Innovation Line Fact Sheet



Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.1: Data acquisition for O&M digitalisation

7.1.6 Means of inspecting structural and operational status triggered on demand by environmental events rather than through continuous monitoring

Development of on-demand inspection and diagnostic approaches that are activated by environmental events rather than relying on continuous monitoring. The line targets event-trigger definitions, rapid data acquisition (temporary sensors, drones/ROVs, vessel-based surveys) and fast analytics to confirm structural/operational integrity, supporting risk-based decisions on restart, inspection scope and maintenance actions.

Technological Objective

To reduce O&M cost and data burden while maintaining integrity assurance by enabling reliable event-triggered inspections that rapidly verify structural condition and operational readiness after extreme or abnormal environmental events.

Specific Actions

- Define event triggers and thresholds linked to integrity risks (motions/accelerations, mooring tensions, wave/wind exceedance, abnormal offsets) and inspection decision logic
- Develop rapid-deploy inspection toolkits and data capture methods (portable sensors, UAV/ROV payloads, quick-connect instrumentation, NDT spot checks)
- Implement fast processing and assessment workflows (automated reporting, damage indicators, acceptance criteria) integrated with O&M and risk management systems

Validation and Trial Needs

- Demonstration through storm/event case studies to validate trigger thresholds, false alarm rates and decision outcomes
- Field trials of rapid-deploy inspection methods in offshore conditions, verifying data quality and time-to-assessment
- Benchmarking against continuous monitoring approaches to quantify cost, response time and integrity assurance performance

Expected Results

- Event-triggered inspection protocols and toolkits enabling faster post-event integrity confirmation
- Reduced O&M and inspection costs through targeted post-event assessment and more efficient mobilisation of inspection resources
- Improved decision-making for restart, inspection prioritisation and maintenance planning after extreme events

Current TRL

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Innovation Line
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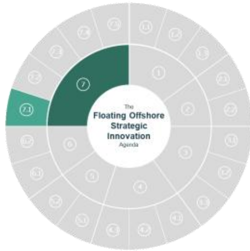

Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.1: Data acquisition for O&M digitalisation

7.1.7 Virtual sensing

Development of virtual sensing methodologies that estimate unmeasured loads, motions and structural states using numerical coupled models (aero-hydro-servo-elastic, mooring and structural response) updated with limited measured data. The line targets reducing physical sensor footprint while enabling reliable condition indicators (fatigue damage, extreme loads, offsets, component utilisation) for integrity management, anomaly detection and digital O&M workflows.

Technological Objective

To enable cost-effective, scalable O&M digitalisation by providing validated virtual sensors that deliver accurate estimates of key structural and operational parameters, supporting condition-based maintenance and reliability management with reduced instrumentation.

Specific Actions

- Develop coupled-model-based virtual sensing architectures (state estimation, model updating, observers) using limited measurements (SCADA, IMUs, strain/acceleration, mooring tension)
- Define data assimilation and uncertainty quantification methods to ensure traceable accuracy of estimated states and derived KPIs (fatigue, utilisation, offsets)
- Implement deployment-ready workflows integrating virtual sensing outputs into O&M systems (alerts, dashboards, inspection planning, digital twin interfaces)

Validation and Trial Needs

- Validation against instrumented reference assets (full/partial sensor suites) to quantify accuracy across operational and extreme conditions
- Robustness testing for model uncertainty, sensor failures and changing environmental conditions (drift, biofouling, degradation)
- Pilot deployment demonstrating O&M value (reduced sensors, improved diagnostics, maintenance decisions) and benchmarking vs traditional sensing

Expected Results

- Virtual sensing toolchain providing reliable estimates of critical loads and structural states with quantified uncertainty
- Reduced sensor CAPEX/OPEX and simplified offshore instrumentation/maintenance
- Improved integrity management and condition-based maintenance through model-informed KPIs and anomaly detection

Current TRL

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Innovation Line
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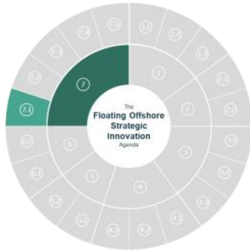

Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.1: Data acquisition for O&M digitalisation

7.1.8 Implementation of lightweight, multi-vector inspection methods for conducting group inspections, including deployment from Uncrewed Surface Vessels

Implementation of lightweight, multi-vector inspection methods to perform group inspections across floating wind assets using coordinated deployment of multiple platforms and sensors. The line targets scalable inspection concepts for structural and operational condition checks (hull, freeboard zone, moorings, dynamic cable interfaces, topside elements), improving coverage, reducing vessel time and enabling rapid inspection campaigns with standardised data outputs.

Technological Objective

To enable efficient, repeatable group inspections of multiple floating wind units through coordinated multi-vector deployments integrating USVs, UAVs and UUVs, delivering reliable condition information with reduced offshore logistics, improved HSE and seamless integration into digital O&M workflows.

Specific Actions

- Develop multi-vector inspection concepts and mission planning tools (tasking, navigation, comms, safety/exclusion zones)
- Integrate lightweight sensor payloads and standardised data formats (vision/sonar/LiDAR as applicable) with automated processing pipelines
- Define operational procedures and acceptance criteria for group inspections (coverage metrics, detectability thresholds, reporting templates)

Validation and Trial Needs

- Field trials of coordinated multi-vector inspection missions integrating USVs, UAVs and UUVs under representative sea states and operational conditions, including validation of multi-platform deployment, recovery and operational coordination procedures
- Verification of data quality and defect/condition detectability versus baseline inspection methods for subsea and topside assets (manned vessel/diver/standalone ROV/manual topside inspection methods)
- Demonstration of end-to-end workflow with quantified time/cost/HSE benefits

Expected Results

- Scalable group inspection capability with reduced vessel days and demonstrable reductions in vessel support requirements compared with conventional inspection plans
- Higher consistency and traceability of inspection outputs through standardised multi-vector methods
- Faster condition assessment and prioritised maintenance planning via digital, semi-automated reporting

Current TRL

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Innovation Line
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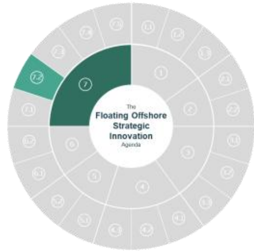

Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.2: Data management and structuring for O&M digitalisation

7.2.1 Operational digital twins for floating offshore wind behaviour monitoring, load tracking and degradation prediction

Development of operational digital twins combining real-time data, historical performance records, validated physics-based models and data-driven / machine learning approaches to simulate structural behaviour, track loads, predict degradation and support secure predictive maintenance strategies for floating wind assets.

Technological Objective

To improve prediction of structural and mechanical degradation mechanisms and enable risk-informed O&M planning through digital twin systems that reflect real operating conditions, asset response, evolving degradation behaviour and predictive maintenance needs under secure operational architectures.

Specific Actions

- Identification of key parameters and degradation mechanisms to be captured for turbines, floating platforms, moorings and dynamic cables
- Development of digital twin models integrating aerodynamics, hydrodynamics, control dynamics, structural dynamics, fatigue behaviour and validated data-driven prediction capabilities
- Integration of multi-source data streams (monitoring sensors, inspection data, SCADA, metocean observations) into secure real-time twin updating algorithms
- Development of methodologies for model validation, uncertainty reduction, long-term performance prediction and predictive maintenance support

Validation and Trial Needs

- Pilot implementation of operational digital twins in active floating wind turbines and platforms
- Validation of model predictions against measured responses, degradation indicators and historical failure patterns
- Assessment of data quality, update frequency, computational performance and robustness under variable operating conditions
- Evaluation of impact on maintenance planning, inspection intervals and cost reduction

Expected Results

- Improved understanding of asset behaviour and degradation under real offshore conditions
- More accurate prediction of fatigue, wear and failure mechanisms
- Better-informed O&M strategies, including optimised inspection and predictive maintenance schedules
- Reduction of unexpected failures and increased floating wind asset availability

Current TRL

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Innovation Line
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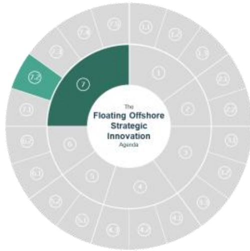

Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.2: Data management and structuring for O&M digitalisation

7.2.2 Industrial data platforms and advanced analytics for floating wind operations

Development of industrial data platforms, cybersecurity frameworks and advanced analytics solutions for floating wind operations, capable of ingesting, structuring and managing large volumes of operational data from monitoring systems, inspections and digital twins. These platforms enable scalable data integration, interoperability and advanced analytics to support O&M digitalisation and asset performance optimisation.

Technological Objective

To enable scalable integration, management and advanced analytics of operational data from floating wind assets through interoperable industrial data platforms supporting digital twins and data-driven O&M strategies.

Specific Actions

- Definition of data governance and architecture frameworks for floating wind digital ecosystems
- Integration of heterogeneous operational data sources (SCADA, monitoring systems, inspection data and digital twins) into unified industrial data platforms
- Development of advanced analytics environments enabling large-scale data processing, predictive modelling and operational optimisation
- Implementation of cybersecurity, access control and data lineage mechanisms to ensure secure and traceable management of critical operational data
- Development of edge-level data acquisition and communication architectures for reliable collection and transmission

Validation and Trial Needs

- Deployment of industrial data platforms in representative floating wind operational environments
- Verification of data integrity, interoperability and traceability across monitoring systems, digital twins and operational platforms
- Assessment of analytics performance and platform robustness under high data volumes and limited offshore communication bandwidth
- Validation of platform integration with operational decision-making and asset management workflows

Expected Results

- Improved accessibility, traceability and quality of operational data from floating wind assets
- Enhanced capability to deploy advanced analytics and predictive models at operational scale
- Improved coordination between operators, OEMs and service providers through interoperable digital ecosystems
- Reduced O&M costs through data-driven decision-making and scalable analytics workflows

Current TRL

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Innovation Line
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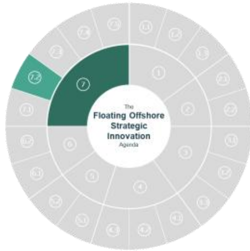

Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.2: Data management and structuring for O&M digitalisation

7.2.3 Holistic multi-component data integration platforms

Development of integrated data platforms capable of merging information from multiple floating wind components - turbine, platform, moorings, dynamic cables, electrical systems and environmental data - into a unified and interoperable framework. The focus is on enabling cross-component correlation to identify emerging degradation and failure patterns at both asset and wind-farm scale, supporting advanced diagnostics, predictive analytics and lifecycle-informed O&M decision-making.

Technological Objective

To provide comprehensive asset-level and farm-level situational awareness by correlating diverse data streams through interoperable and robust data integration frameworks, improving detection of complex degradation mechanisms, cascading failure risks and advanced O&M decision-making.

Specific Actions

- Definition of prioritised cross-component data models focusing on the most relevant interactions between key subsystems (e.g. floater-mooring, mooring-dynamic cable, turbine-floater) and environmental inputs
- Integration of multi-component analysis outputs into asset-level and fleet-level integrity management and predictive maintenance frameworks
- Development of interoperable integration frameworks capable of merging structural, mechanical, electrical, environmental and SCADA data
- Development of data governance and consistency verification approaches supporting reliable lifecycle integrity assessment, Remaining Useful Life (RUL) estimation and configuration traceability

Validation and Trial Needs

- Application of multi-component integration platforms to representative floating wind operational datasets
- Assessment of data quality, interoperability, latency and consistency in representative operational environments
- Verification of platform performance in identifying correlated degradation and failure indicators across moorings, cables, structures and turbine components
- Validation of robustness against configuration evolution, component replacement and long-term dataset continuity scenarios

Expected Results

- Improved understanding of system-level behaviour, interdependencies and degradation propagation mechanisms
- More effective O&M planning through integrated diagnostics, predictive analytics and lifecycle-informed decision-making
- Earlier identification of complex failure mechanisms driven by multi-component interactions
- Improved reliability and consistency of multi-component integrity assessment and Remaining Useful Life estimation

Current TRL

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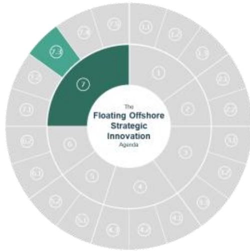

Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.3: Data exploitation for O&M digitalisation

7.3.1 Probabilistic integrity management frameworks (MIM / CMIM) at commercial scale

Development and implementation of probabilistic integrity management frameworks for floating wind mooring systems, integrating inspection data, monitoring results, load history, degradation models and structured lifecycle datasets. These frameworks aim to quantify failure probabilities, optimise inspection intervals and support risk-informed and predictive O&M decisions at commercial wind farm scale while accounting for operational uncertainty, data quality and configuration variability.

Technological Objective

To provide robust, data-driven methodologies for managing the integrity of mooring lines and station-keeping systems through probabilistic models that reflect real asset behaviour, uncertainty, operational variability, predictive maintenance needs and lifecycle data consistency.

Specific Actions

- Development of probabilistic models incorporating monitoring data, inspection records, fatigue analysis, corrosion progression, metocean and uncertainty propagation methodologies
- Definition of risk-based inspection and maintenance criteria aligned with floating wind operational constraints and data quality management requirements
- Integration of MIM/CMIM methodologies with digital twins, predictive analytics and O&M planning workflows for risk-informed maintenance and intervention decision-making
- Development of data governance, consistency verification and configuration management approaches supporting reliable integrity assessment and Remaining Useful Life (RUL) estimation

Validation and Trial Needs

- Application of probabilistic integrity management models to operational floating wind datasets at asset or farm scale
- Verification of predicted degradation trends against inspection findings and observed performance
- Assessment of risk reduction and OPEX impacts compared with deterministic or time-based integrity management approaches

Expected Results

- Improved prediction of degradation and failure likelihood for station-keeping systems with increased confidence in integrity and RUL estimates
- More efficient, predictive and risk-based inspection and maintenance planning supported by probabilistic and data-quality-aware methodologies
- Reduced probability of unexpected mooring or anchoring failures at commercial floating wind scale through improved integrity assessment reliability and uncertainty management

Current TRL

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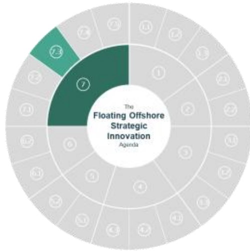

Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.3: Data exploitation for O&M digitalisation

7.3.2 Digital workflows and tools for tow-to-port and on-site maintenance

Development and deployment of digital workflows and decision-support tools to plan, coordinate and execute tow-to-port and on-site maintenance operations for floating wind assets. These tools integrate asset condition data, metocean forecasts, port availability, vessel logistics and operational risks to optimise maintenance planning, support operational decision-making and minimise downtime during major maintenance activities.

Technological Objective

To improve the planning, coordination and safety of tow-to-port and on-site maintenance operations through digital workflows and decision-support tools that optimise scheduling, operational execution and downtime management for major maintenance activities.

Specific Actions

- Definition of decision criteria and triggering thresholds for tow-to-port or on-site maintenance interventions based on asset condition, operational risk and site-specific spatial and regulatory constraints
- Integration of metocean data, logistics constraints, vessel availability and port capacity into digital maintenance planning environments
- Development of workflow management tools coordinating stakeholders (operators, ports, vessel providers and OEMs) during maintenance campaigns

Validation and Trial Needs

- Application of digital tow-to-port workflows to representative floating wind maintenance scenarios
- Verification of downtime reduction, improved coordination and risk mitigation compared to ad hoc planning approaches
- Assessment of operational performance during real or simulated tow-to-port and offshore maintenance campaigns

Expected Results

- Reduced operational risk and downtime associated with major maintenance
- Improved coordination between offshore operations, port-based activities and maintenance logistics
- Increased predictability and cost control in major maintenance interventions

Current TRL

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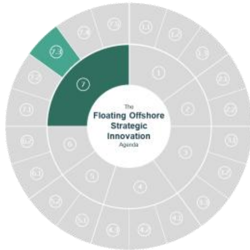

Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.3: Data exploitation for O&M digitalisation

7.3.3 Digital workflows and tools for site-replacement maintenance

Development of digital workflows and decision-support tools to enable offshore, in-situ replacement of critical components in floating wind systems. These tools integrate asset condition data, metocean forecasts, vessel and lifting capacity, safety constraints and operational risk to support safe and efficient execution of site-based maintenance interventions.

Technological Objective

To enable reliable, efficient and low-risk site-replacement operations by providing digital planning, simulation and decision-support tools adapted to floating wind O&M requirements.

Specific Actions

- Definition of operational envelopes and decision criteria for in-situ replacement of major components (for example, blades, dynamic cables, moorings)
- Integration of metocean forecasting, vessel motion limits and lifting constraints into digital planning environments
- Development of workflow tools coordinating multi-asset, multi-vessel offshore interventions under dynamic conditions

Validation and Trial Needs

- Application of digital site-replacement planning tools to representative offshore intervention scenarios
- Verification of operability windows, safety margins and logistical coordination through simulation or pilot offshore operations
- Comparison of intervention efficiency, risk profile and OPEX implications against conventional manual planning approaches

Expected Results

- Increased feasibility and safety of offshore component replacement
- Reduced planning uncertainty and improved execution efficiency
- Greater flexibility between tow-to-port and offshore intervention strategies

Current TRL

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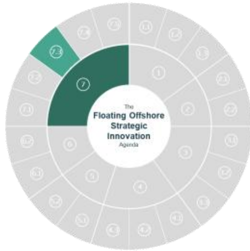

Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.3: Data exploitation for O&M digitalisation

7.3.4 Digital tools for floating asset lifetime extension assessment

Development and deployment of digital tools to assess the technical and economic feasibility of extending the operational life of floating wind assets beyond their original design life, based on structural performance data, degradation trends fatigue accumulation and risk-informed residual life assessment methodologies.

Technological Objective

To enable reliable, risk-informed and economically optimised life extension strategies for floating wind assets through integrated digital assessment methodologies incorporating uncertainty management, operational data integration and residual life evaluation capabilities.

Specific Actions

- Definition of life extension assessment frameworks incorporating structural integrity, mooring system performance, dynamic cable degradation and uncertainty evaluation methodologies
- Integration of operational monitoring and inspection data into digital models for residual life assessment and Remaining Useful Life (RUL) estimation
- Development of criteria and decision-support tools linking technical feasibility with economic performance, risk exposure and regulatory requirements

Validation and Trial Needs

- Application of life extension assessment tools to representative floating wind assets approaching mid-life operation
- Verification of degradation predictions and residual life estimations through inspection and monitoring data
- Review of assessment methodologies with certification bodies and regulatory stakeholders

Expected Results

- Increased confidence and reduced uncertainty in residual life and Remaining Useful Life (RUL) estimation for floating wind systems
- More robust and risk-informed decision-making regarding refurbishment, component replacement or decommissioning
- Quantified lifecycle value and OPEX impacts of life extension strategies, supporting improved return on investment for floating wind projects

Current TRL

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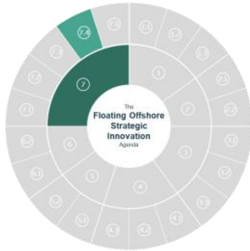

Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.4: Heavy offshore maintenance and major offshore interventions

7.4.1 Heavy lifting and motion-compensated handling solutions

Development and demonstration of heavy lifting and motion-compensated handling solutions for offshore replacement of large floating wind components. These systems incorporate advanced motion compensation technologies to enable safe lifting operations under dynamic vessel and platform motions.

Technological Objective

To enable reliable and weather-resilient offshore heavy-maintenance activities by providing lifting systems capable of compensating for vessel and platform motions, reducing operational risk and expanding viable weather windows.

Specific Actions

- Assessment of motion characteristics and operational envelopes relevant to floating wind heavy lifting scenarios
- Adaptation and qualification of active motion compensation technologies for floating wind component geometries and load cases
- Development of operational procedures integrating compensated lifting systems with vessel and platform behaviour

Validation and Trial Needs

- Full-scale or near-full-scale offshore trials to assess performance of motion-compensated lifting systems under representative metocean conditions
- Verification of lifting accuracy, load stability and operational safety during the handling of large components
- Evaluation of system reliability, energy consumption, maintainability and operational limits
- Assessment of compatibility with vessels, auxiliary platforms, deck layouts and at-sea replacement procedures

Expected Results

- Increased feasibility and safety of offshore replacement of blades, nacelles, tower sections and cable modules
- Expanded operational weather windows through advanced motion-compensation capabilities
- Greater flexibility between offshore replacement and tow-to-port maintenance strategies, with reduced reliance on tow-to-port where feasible

Current TRL

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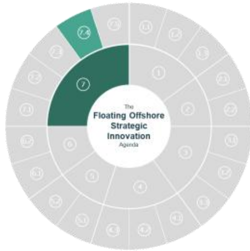

Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.4: Heavy offshore maintenance and major offshore interventions

7.4.2 Specialised offshore vessels and floating support platforms for FOW maintenance

Development and adaptation of specialised offshore vessels and floating support platforms for major maintenance operations in floating offshore wind, including enhanced station-keeping, handling systems, robotic support capabilities and validated data-driven operational models where relevant. The focus is on enabling safe heavy interventions, component replacement and offshore repair under dynamic operational conditions.

Technological Objective

To enable safe and efficient major offshore maintenance operations for floating wind farms through specialised offshore vessels and floating support platforms equipped with advanced station-keeping, handling, support and data-driven operational capabilities adapted to floating wind intervention needs.

Specific Actions

- Definition of functional and operational requirements for specialised offshore vessels and floating support platforms performing major maintenance operations in floating wind farms
- Development and adaptation of specialised vessel and floating support platform concepts incorporating enhanced station-keeping, motion reduction and optimised deck layouts for component replacement
- Integration and assessment of robotic and autonomous support systems (e.g. USV-assisted logistics or inspection support) to improve operational efficiency and safety
- Development and validation of data-driven and machine learning models supporting operability assessment, motion prediction and offshore intervention planning
- Assessment of compatibility between vessel/platform concepts, heavy lifting systems and floating wind component geometries and interfaces

Validation and Trial Needs

- Representative trials of adapted offshore support concepts, robotic support systems and data-driven operational tools under relevant floating wind operational conditions
- Verification of station-keeping, motion mitigation, robotic support performance and operational safety during simulated or representative maintenance operations
- Assessment of operational limits, energy consumption, logistics efficiency and compatibility with motion-compensated lifting systems and robotic support solutions

Expected Results

- Expanded capability for offshore execution of major maintenance operations
- Increased operational weather windows through improved vessel and platform stability
- Reduced reliance on tow-to-port strategies for major component replacement
- Lower maintenance costs and improved availability of floating wind assets

Current TRL

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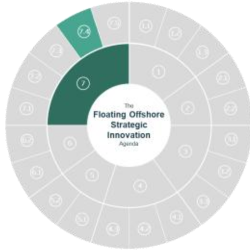

Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.4: Heavy offshore maintenance and major offshore interventions

7.4.3 Procedures and tools for offshore replacement of critical components

Development and validation of standardised procedures, dedicated tools and qualification frameworks enabling the offshore replacement of critical floating wind components, including mooring lines, dynamic cables, structural elements, electrical equipment and major turbine components. The line focuses on increasing repeatability, safety and operational robustness of at-sea replacement activities while enabling emerging solutions for on-demand manufacturing of certified spare parts offshore and ensuring personnel readiness for complex intervention operations.

Technological Objective

To enable reliable and repeatable offshore replacement of critical floating wind components through validated procedures, dedicated intervention tools and qualification frameworks that reduce operational risk, minimise reliance on tow-to-port maintenance strategies and support safe execution by trained and certified offshore personnel.

Specific Actions

- Identification of component interfaces, operational constraints and operability envelopes associated with offshore replacement of moorings, dynamic cables, structural elements, electrical equipment and major turbine components
- Development of standardised offshore replacement procedures incorporating safety margins, motion constraints and operational sequencing for floating wind interventions
- Development and qualification of specialised tools and fixtures for manipulation, disconnection and installation of large offshore components
- Development of qualification, certification and simulation-based training approaches for offshore personnel involved in major intervention operations
- Assessment of emerging solutions for on-demand manufacturing and certification of spare parts to support offshore maintenance logistics

Validation and Trial Needs

- Offshore trials demonstrating reliability of replacement procedures under representative metocean and motion conditions
- Verification of tool performance, operational limits and compatibility with component interfaces and vessel/platform configurations
- Assessment of procedure repeatability and operational efficiency across different floating wind turbine configurations
- Validation of certification and quality assurance approaches for spare parts produced through distributed or on-demand manufacturing solutions
- Use of simulation environments, onshore testing and scaled validation approaches where appropriate prior to full offshore demonstration

Expected Results

- Standardised, safer and more efficient offshore replacement methods for critical components
- Increased repeatability and predictability of major offshore maintenance operations
- Expanded capability for at-sea maintenance interventions, reducing reliance on tow-to-port strategies
- Improved personnel readiness and operational safety through validated qualification and simulation-based training approaches
- Improved logistics flexibility through emerging on-demand manufacturing approaches for certified spare parts

Current TRL

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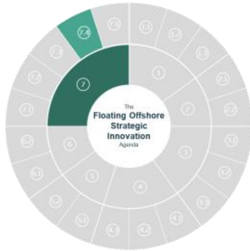

Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.4: Heavy offshore maintenance and major offshore interventions

7.4.4 Advanced planning, risk modelling and decision-support systems for major interventions

Development of advanced planning tools and decision-support systems to optimise the preparation and execution of major offshore interventions in floating wind farms. These systems integrate metocean data, asset condition information, vessel and equipment availability, logistical constraints, SIMOPS management, motion-related operational limits and human-factor considerations to support safe, reliable and efficient offshore operations.

Technological Objective

To provide robust data-driven planning and risk modelling capabilities that improve the safety, predictability and effectiveness of major offshore interventions, while supporting human-centred operational decision-making, dynamic risk management and safe execution under complex offshore conditions.

Specific Actions

- Definition of multi-parameter decision frameworks combining asset health indicators, metocean limits, operational resource constraints and dynamic go/no-go criteria
- Development and integration of simulation and digital modelling tools to evaluate intervention sequences, lifting operations, weather operability windows and SIMOPS scenarios
- Development of user-oriented planning platforms and digital dashboards integrating role-based operational support, decision traceability and coordination between operators, contractors and vessel providers
- Integration of training-ready capabilities enabling operational rehearsal, scenario simulation and competency validation for offshore teams

Validation and Trial Needs

- Application of planning and decision-support systems to representative major intervention scenarios, including procedure rehearsal and operational simulation
- Verification of system accuracy in predicting operational windows, task duration, resource needs and human-factor-related operational constraints
- Assessment of intervention efficiency gains and reduction of unplanned delays using simulated or historical maintenance campaigns

Expected Results

- Improved predictability, coordination and operational reliability of complex offshore maintenance operations
- Expanded operability windows through improved forecasting, integrated planning tools and enhanced offshore decision-support capabilities
- Reduced intervention risk, operational delays, cost uncertainty and human-error-related incidents at wind farm scale
- Accelerated industrialisation of offshore maintenance campaigns through standardised planning, decision-support and training frameworks

Current TRL

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Current TRL					

Innovation Line
Fact Sheet

Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.4: Heavy offshore maintenance and major offshore interventions

7.4.5 Maintenance strategy trade-offs analysis (in situ vs. offshore)

Development of methodologies and decision-support tools to compare heavy maintenance strategies for floating wind assets, assessing in situ maintenance versus offshore-oriented concepts (tow-to-port, offshore exchange, specialist vessels). The line targets structured evaluation of technical feasibility, cost, logistics, HSE risk and downtime impacts under site-specific constraints, enabling robust maintenance planning and selection of optimal intervention concepts.

Technological Objective

To enable selection of the most cost-effective and risk-robust heavy maintenance strategy by providing standardised trade-off analysis methods that quantify feasibility, logistics, downtime and total cost impacts for in situ versus offshore-oriented intervention concepts.

Specific Actions

- Develop comparative assessment frameworks combining technical feasibility, metocean operability, logistics (vessels/ports) and HSE risk into consistent KPIs and decision criteria
- Build cost and downtime models capturing mobilisation, weather windows, resource constraints, spares strategy and schedule impacts for each maintenance concept
- Define standardised scenario sets, input assumptions and uncertainty ranges (asset types, distances, port capability, grid constraints) to enable repeatable, auditable and risk-informed comparisons at FEED/O&M planning stages

Validation and Trial Needs

- Application to representative project case studies to benchmark outcomes against operator experience and historical intervention data
- Sensitivity and uncertainty analysis to test robustness to metocean variability, failure rates, vessel availability and cost assumptions
- Demonstration of tool integration into O&M planning processes (maintenance scheduling, spares, contracting strategy) with documented decision traceability

Expected Results

- Decision-support methodology delivering transparent comparisons of in situ against offshore-oriented heavy maintenance concepts
- Optimised intervention strategies reducing downtime and total O&M cost while improving HSE performance
- More bankable O&M plans through auditable assumptions, clearer risk allocation and improved logistics planning

Current TRL

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Innovation Line
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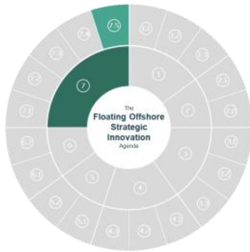

Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.5: Decommissioning, repowering and end-of-life strategies of the floating system

7.5.1 Technologies for safe disconnection of moorings, anchors, cables, and electrical systems

Development of procedures, tools and technologies to safely execute the disconnection of mooring systems, dynamic cables and electrical interfaces during floating wind decommissioning operations. The focus is on enabling controlled hook-down operations, minimising offshore risks and ensuring predictable, low-impact asset removal under variable metocean conditions.

Technological Objective

To enable reliable, standardised and safe offshore disconnection of floating wind systems through controlled release of moorings, dynamic cables and electrical interfaces while reducing risks to personnel, vessels and the environment.

Specific Actions

- Definition of operational requirements and safety constraints for disconnection of mooring lines, anchors, dynamic cables and electrical interfaces
- Development of specialised tools and systems for controlled hook-down, line tension management, cutting, securing and lifting operations
- Identification of key operational risks, operational envelopes and contingency procedures for disconnection operations under variable metocean conditions

Validation and Trial Needs

- Demonstration of disconnection procedures during pilot decommissioning operations or controlled offshore trials
- Verification of controlled tension release, handling stability and safe recovery of moorings and dynamic cables
- Assessment of procedural reliability, operational limits and required vessel capabilities

Expected Results

- Safer and more predictable disconnection of mooring, cable and electrical systems during floating wind decommissioning
- Reduced risk of uncontrolled line release, equipment damage or environmental impact
- More efficient decommissioning workflows with reduced offshore exposure
- Lower operational costs and improved planning reliability for end-of-life operations

Current TRL

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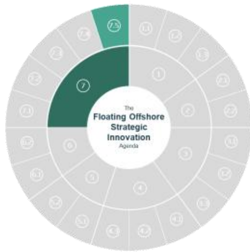

Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.5: Decommissioning, repowering and end-of-life strategies of the floating system

7.5.2 Optimised strategies for removal and tow-back of floating platforms

Development of optimised strategies, operational procedures and dedicated tools for the safe and efficient removal of floating wind platforms and their tow-back to port during decommissioning. The focus is on minimising offshore risks, operational time and environmental impacts while optimising single-unit and wind-farm-scale tow-back campaigns under variable metocean conditions.

Technological Objective

To enable predictable, low-risk and cost-effective removal operations with minimum environmental impact by improving tow-back planning, platform handling, towing configurations and offshore-to-port logistical coordination.

Specific Actions

- Definition of removal architectures considering platform configuration, residual loads, mooring disconnection sequence and location-specific operational constraints
- Assessment of towing strategies, platform stability and vessel support requirements for intact and partially dismantled floating units under representative metocean conditions and tow-back scenarios, including ballast and de-ballast management considerations
- Integration of port logistics, towing distances, vessel availability and dismantling strategies into removal planning frameworks
- Assessment of ballast water handling, treatment and disposal requirements associated with floating platform decommissioning and tow-back operations

Validation and Trial Needs

- Application of optimised removal and tow-back strategies to representative floating wind decommissioning scenarios
- Verification of platform stability, towing line loads, dynamic behaviour and fuel/energy requirements during tow-back
- Assessment of operational limits, towing speeds, vessel requirements and coordination with port infrastructure
- Evaluation of port capabilities for ballast water handling and treatment, as well as management of decommissioning-related waste streams

Expected Results

- Reduced operational risk during removal and tow-back phases
- Improved coordination between offshore removal and onshore dismantling activities
- Increased predictability and cost optimisation in end-of-life floating wind campaigns

Current TRL

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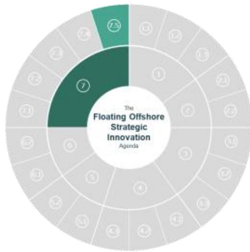


Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.5: Decommissioning, repowering and end-of-life strategies of the floating system

7.5.3 Modular dismantling technologies enabling circular reuse of floating wind components offshore and in port

Development of modular dismantling technologies and engineered methods to enable progressive deconstruction of floating wind turbines, platforms and auxiliary systems both offshore and in port. These approaches support safe and efficient dismantling operations while enabling refurbishment, reuse and recycling of modular components, contributing to circular lifecycle management of floating wind assets and leveraging validated lifecycle operational datasets generated during design and operation phases.

Technological Objective

To enable safe, efficient and repeatable dismantling solutions that minimise offshore risk exposure, reduce logistical complexity and support circular end-of-life strategies through modular, step-by-step deconstruction processes and traceable lifecycle information.

Specific Actions

- Definition of dismantling sequences and modular break-down strategies suitable for different floating wind system architectures
- Development of dedicated dismantling tools and handling frames enabling safe progressive disassembly offshore and in port
- Integration of lifecycle asset data, configuration traceability and operational constraints into dismantling planning and execution methodologies
- Integration of dismantling strategies with recycling and material recovery processes to maximise reuse, recyclability and traceability of components

Validation and Trial Needs

- Application of modular dismantling approaches to representative floating wind decommissioning scenarios
- Validation of dismantling tool performance through controlled trials and representative offshore and onshore dismantling scenarios, including assessment of operational limits, safety margins, precision and repeatability
- Assessment of dismantling efficiency, waste minimisation, material recovery rates and reuse potential of recovered components

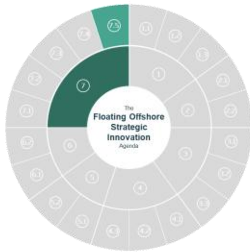
Expected Results

- Safer and more predictable dismantling operations with reduced offshore personnel exposure
- More efficient decommissioning workflows through modular, stepwise deconstruction strategies
- Increased reuse, refurbishment and recycling potential of floating wind components and materials
- Improved traceability and repeatability of end-of-life operations through lifecycle-informed dismantling methodologies

Current TRL

	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Current TRL					

Innovation Line Fact Sheet



Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.5: Decommissioning, repowering and end-of-life strategies of the floating system

7.5.4 Planning, risk modelling and simulation tools specific to decommissioning operations

Development of digital planning and simulation tools to support floating wind decommissioning operations. These tools model uninstallation sequences, vessel logistics, metocean constraints, component behaviour, operational risks and environmental footprint implications, enabling scenario-based optimisation of removal strategies. The line also includes the adaptation of installation and heavy-maintenance simulation models, supported by structured lifecycle datasets to improve operational predictability, decision-support capabilities and risk-informed planning.

Technological Objective

To enable accurate, efficient and risk-informed planning of floating wind decommissioning campaigns through advanced simulation environments, structured operational datasets and decision-support capabilities that improve predictability, optimise removal sequences, reduce operational uncertainty and support environmentally informed decommissioning strategies.

Specific Actions

- Adaptation of installation and heavy-maintenance simulation models to end-of-life scenarios, including alternative load paths and dismantling configurations
- Development of decommissioning-specific risk assessment and operability evaluation frameworks
- Integration of logistical, port, vessel and environmental footprint considerations into digital planning environments for decommissioning campaigns
- Development and integration of structured operational datasets and data-driven decision-support tools for optimisation of removal planning and execution strategies

Validation and Trial Needs

- Application of decommissioning planning and simulation tools to representative floating wind end-of-life scenarios
- Verification of prediction accuracy for operation duration, vessel logistics, weather windows, dismantling constraints and environmental impact estimation
- Assessment of usability, robustness and decision-support capability under variable operational conditions

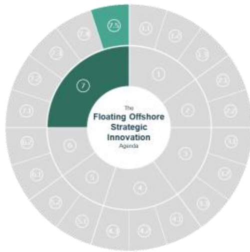
Expected Results

- Improved coordination and predictability of complex decommissioning operations
- Reduced operational risk and uncertainty during end-of-life campaigns
- More efficient integration between offshore removal, tow-back and onshore dismantling or recycling phases
- Improved decision-support capability through validated lifecycle datasets and enhanced operational planning tools
- Increased ability to compare and optimise decommissioning scenarios considering operational, logistical and environmental footprint criteria

Current TRL

	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Current TRL					

Innovation Line
Fact Sheet



Lifecycle Stage: O&M and Decommissioning

Area 7: Operation & Maintenance and Decommissioning

Subarea 7.5: Decommissioning, repowering and end-of-life strategies of the floating system

7.5.5 Environmental impact assessment and disposal strategies for floating wind decommissioning

Development of applied methodologies to assess and minimise environmental impacts during floating wind decommissioning, addressing regulatory requirements and gaps while defining practical end-of-life pathways. The line covers removal operations, seabed disturbance, waste streams and treatment routes, as well as decision frameworks for reuse, repowering, recycling and final disposal of offshore infrastructure, aligned with industrial feasibility, permitting needs and lifecycle sustainability considerations.

Technological Objective

To enable environmentally robust and regulator-ready decommissioning by providing standardised impact assessment approaches and implementable end-of-life strategies that minimise seabed disturbance, reduce ecosystem impacts and support feasible reuse, recycling and disposal pathways while considering lifecycle operational and environmental performance..

Specific Actions

- Develop decommissioning impact assessment methodologies covering removal scenarios, seabed disturbance, emissions / noise and waste streams, including cumulative aspects where relevant
- Map regulatory requirements, permitting expectations and compliance pathways across relevant jurisdictions for floating wind assets
- Define end-of-life option frameworks and logistics for reuse, repowering, recycling and disposal routes, including lifecycle environmental and operational assessment criteria
- Assessment of the economic viability and cost implications of alternative end-of-life pathways, including reuse, repowering, recycling and disposal routes
- Development of lifecycle-informed design recommendations to improve future reuse, recyclability, life extension and environmentally efficient decommissioning of floating wind components and substructures

Validation and Trial Needs

- Case study application on representative floating wind projects to benchmark impacts and validate decision frameworks against permitting expectations
- Validation of waste and material flows (including hazardous materials) and feasibility of recycling/reuse routes with industry and supply-chain stakeholders
- Pilot demonstrations of selected end-of-life operations (component removal, segregation, transport, recycling trials) to confirm practicality and environmental performance

Expected Results

- Standardised but adaptable methodologies and templates for environmental assessment and end-of-life planning aligned with different regulatory and permitting contexts
- Reduced consenting risk and improved environmental performance through traceable, best-practice decommissioning plans supported by lifecycle-based assessment approaches
- Clear, implementable end-of-life pathways increasing reuse/recycling rates and reducing final disposal volumes
- Improved consideration of end-of-life and environmental constraints in future floating wind component and substructure design

Current TRL

	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Current TRL					