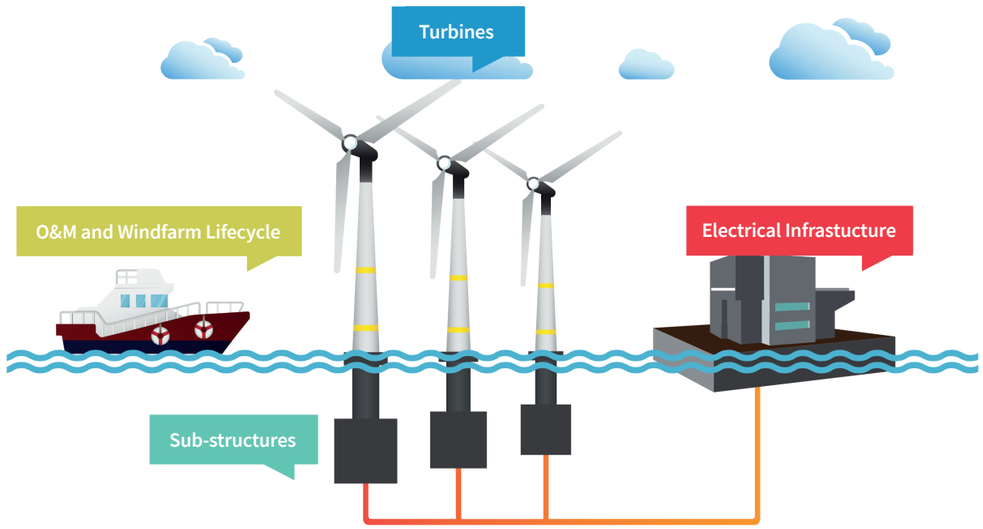
Offshore Wind
Innovation
Hub

INNOVATION ROADMAPS



ABOUT US

Funded by the Department for Business, Energy and Industrial Strategy (BEIS) and delivered jointly by the Offshore Renewable Energy (ORE) Catapult and Innovate UK's Knowledge Transfer Network (KTN), the Offshore Wind Innovation Hub is the UK's primary coordinating body for innovation to reduce the cost of offshore wind energy and grow UK jobs in the sector. It coordinates with industry, supply chain and academia to provide Government and industry with an impartial, inclusive and trusted view of the innovation needs of the UK offshore wind sector, supply chain growth opportunities, and a comprehensive view of the funding landscape in offshore wind.

INNOVATION ROADMAPS

The UK offshore wind industry aims to supply one third of the country's electricity from offshore wind by 2030. This vision includes more than doubling the current generation capacity to reach 30GW by 2030 and has the potential to create 27,000 skilled jobs. In order to achieve this ambition, it is vital to understand the areas of offshore wind where there is a demand for innovation. The Offshore Wind Innovation Hub, in collaboration with industry and academia, has developed a set of technology innovation roadmaps. These are advanced prioritisation tools that identify the innovation needs of the offshore wind sector.

What do the Innovation Roadmaps do?
Provide government and industry with a single, validated source of information on the key challenges and innovation priorities within the UK offshore wind sector.

Identify to innovators and the supply chain where there are potential market opportunities within the UK offshore wind sector.

Provide funders and potential applicants with an evidence base for demonstrating the areas of the UK offshore wind sector that have a demand for innovation.

How are they populated?
The roadmaps build on previous innovation prioritisation work undertaken in the sector, such as the Cost Reduction Monitoring Framework. Based on this foundation, the Hub created a series of roadmaps which were tested with industry and academia through the Hub's Technical Advisory Group.

How often are they updated?
The roadmaps will be updated at least every six months to ensure they continue to accurately reflect the needs of the UK offshore wind sector.

The Offshore Wind Innovation Hub has created four roadmaps (Turbines, Substructures, Electrical Infrastructure, and O&M and Windfarm Lifecycle). This brochure gives an introduction to the four roadmaps and provides some examples of the innovation areas identified.

Full details can be found at the Innovation Hub website
www.offshorewindinnovationhub.com

EXPLAINING THE ROADMAPS

For each one of the Roadmaps we are providing the following details:

Title and description of the Innovation Area:
Technology Readiness Level at the start and end of the innovation area at in the timescales provided

Forecast start and finish:
When the significant progress in this area of innovation is expected to start and finish

Start and Target TRL:
Technology Readiness Level at the start and end of innovation area at timescales provided

Enabler:
Target organisation likely to take a lead on this innovation area delivery e.g. Industry, Academia, Research Technical Organisations

Beneficiary:
Part of the supply chain that would benefit from a solution in this innovation area

Strategic Outcome:
One of 3 general strategic outcomes this innovation area can contribute to:
- enabling >10MW turbine platforms commercialised
- maximising operational performance from existing wind turbines
- enabling disruptive innovation

Potential to Reduce LCoE:
Within the context of this specific roadmap what contribution could the specific innovation area make to reducing Levelised Cost of Energy

UK Benefit:
How well placed is the UK to play a role in the development and maturing of the specific innovation area and benefit from the outcomes

Case for Intervention:
What is the probability that industry would not take this innovation area forward without additional support

O&M AND WIND FARM LIFECYCLE

Innovative services and products that improve Offshore Wind Farm Operations and Maintenance (O&M) over a project lifecycle, including evolution and optimisation of existing methods and development of disruptive solutions that address industry needs.

Innovation areas in Operations are grouped by:
Commercial & Strategy, Coordination & People and Assets & Technical.

Innovation areas for Maintenance are grouped by:
Service and Reactive Maintenance.

OPERATIONS	2018	2023	2028	2033	2038
Commercial & Strategy					
Trade & Yield Optimisation					
Disruptive technologies for day ahead weather & power forecasting					
Improved accuracy of existing day ahead weather & power forecasting					
Grid Notification Tools					
Coordination & People					
Vessels & Access					
Disruptive access forecasting tools ● **FIG. 1**					
Evolution of existing access forecasting tools					
Autonomous Vehicles					
Improving CTVs capability					
Improved access systems					
Fixed offshore bases & motherships					
Marine Coordination					
Advanced crew & vessel optimisation tools					
Advanced communication infrastructure & hardware					
Inventory Management					
Smart spares & equipment tracking					
Integrated inventory/logistic management systems					
Human Factors					
Robotics & autonomous systems to total replacement of human working - development					
Robotics & autonomous systems to total replacement of human working - demonstration ● **FIG. 2**					
Robotics & autonomous systems to total replacement of human working - commercialisation					
Decision making tools to reduce impact on H&S					
Assets & Technical					
Survey & Inspection					
Non-diver based substructure inspection					
Automated data processing					
VLOS autonomous systems					
BVLOS autonomous systems					
Blade subsurface inspection techniques					
Control Optimisation					
Disruptive wind farm wide control					
Proactive turbine control					
Evolution of current wind farm wide control					
Lifetime Management					
OSW Farm Lifetime Management Tool					
Holistic wind farm CMS and SHM					
Monitoring					
Balance of plant CMS					
Low cost metocean measurement infrastructure					
Satellite remote monitoring					

MAINTENANCE	2018	2023	2028	2033	2038
Service					
Statutory inspections					
Decrease variations in between countries					
Planning					
Smart maintenance planning tools					
Servicing					
Automated Servicing					
Reactive Maintenance					
Planned Corrective					
Advanced coatings for substructures					
Advanced blade leading edge protection					
Novel aerodynamics improvements					
Major Repairs					
Blade habitat systems					
CMS and machine learning for component prognosis					
Novel heavy lift systems					

TURBINES

Developing the next generation of offshore wind turbines, enhancing reliability and availability, enabling bigger systems and greater energy capture from the wind. These innovation areas incorporate all the technology that forms the structural and operational elements of the wind turbine generator.

Innovation areas in Turbines are grouped by:
Rotors and Powertrains

	2018	2023	2028	2033	2038
Rotors					
Advanced pitch control					
Pitch Control for floating wind					
Disruptive blades					
Smart blades (flaps, slats, morphing)					
Development of radically different blade structure					
Demonstration of radically different blade structure					
Two bladed turbines					
Thermoplastic blades					
Segmented blades					
Aeroelastic tailoring					
Advanced testing & validation					
Improved full scale testing for 100m+ blade					
NDT procedures					
Fracture Mechanics & Condition monitoring					
Advanced understanding and prediction of failure					
Engineering / Simulation validation of tools for WTG behaviour					
Improved blade structure models					
Disruptive architecture					
High Altitude Aerofoil					
Kites - development					
Kites - commercialisation					
Multi rotor turbines					
Higher efficiency composite manufacturing					
Advanced Composite Manufacture (Automation/Quality Improvement)					
Blade Leading Edge Erosion Solutions ● **FIG.3**					
New Blade Adhesive Bonding Solutions					
Multifunctional systems AI + LDS + EMI					
Lightweight Composites Materials					
Powertrain					
Development of next generation convertors					
Multiple sub-convertors					
Parallel powertrains					
Silicon Carbide Switches in Convertors					
Increased number of steps in MV convertor					
Development of next generation generators					
Non Rare Earth PM Magnets					
Superconducting Wind Turbine Generator					
10MW+ Generator					
Axial Flux Permanent Magnet Generator					
Advanced testing & validation					
Representative Bearing Testing for 10MW+ (BAT					
Drivetrain highly accelerated life time test (HALT)					
Journal bearing testing for wind turbine gearbox					
Alternatives to gearboxes					
Magnetic gearing					
Hydraulic gearing ● **FIG. 4**					
Powertrain design					
Powertrain design for improved reliability					
Advanced understanding and prediction of failure					
Condition monitoring in direct-drive generators					
Prognostic Condition Monitoring					
Acoustic Emissions Condition Monitoring Analysis					
Better understanding of IGBT failure mechanism					

SOME KEY ELEMENTS IN DETAIL

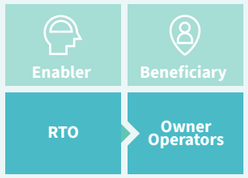
O&M AND WIND FARM LIFECYCLE

Fig 1: Disruptive access forecasting tools

COORDINATION & PEOPLE > VESSELS & ACCESS

Description

Tools are required to accurately forecast the likelihood of access across a wind farm site that makes account for met ocean conditions at specific turbine locations and vessel limitations. Existing tools exist as commercial offerings, but further research on disruptive, next generation tools is worthwhile.



Strategic Outcome

- Disruptive innovation enabled
- Enabling >10MW turbine platforms commercialised
- **Maximise operational performance from existing wind farms**

UK Benefit

Low — Medium — **High**

Potential to reduce LCOE

Low — **Medium** — High

Case for Intervention

Low — Medium — **High**

Forecast start to finish

Now — **2020** — **2025** — 2030 — 2035 — 2040

Technology Readiness Level

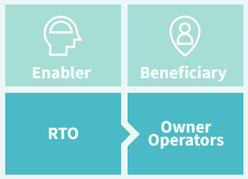
1 — 2 — 3 — **4** — **5** — **6** — **7** — 8 — 9

Fig 2: Robotics & autonomous systems to total replacement of human working – demonstration

COORDINATION & PEOPLE > HUMAN FACTORS

Description

The displacement of humans from repetitive and/or high-risk tasks by deployment of entirely autonomous robotic systems. Example: repetitive bolt check or inspection tasks, where a human operator is only informed in event of an anomaly or event requiring their attention.



Strategic Outcome

- **Disruptive innovation enabled**
- Enabling >10MW turbine platforms commercialised
- Maximise operational performance from existing wind farms

UK Benefit

Low — Medium — **High**

Potential to reduce LCOE

Low — Medium — **High**

Case for Intervention

Low — **Medium** — High

Forecast start to finish

Now — **2020** — **2025** — **2030** — 2035 — 2040

Technology Readiness Level

1 — 2 — 3 — **4** — **5** — **6** — **7** — 8 — 9

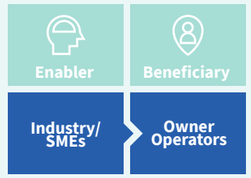
TURBINES

Fig 3: Blade leading edge erosion solutions

ROTORS > DEVELOPMENT OF ADVANCED MATERIALS

Description

Leading Edge Erosion (LEE) is known to occur when precipitation in the atmosphere and other airborne particulates impinge on wind turbine blades rotating at high velocities. Developing solutions that protect against LEE for the blade lifetime and that allows higher tip-speed would be highly beneficial to extend blade lifetime and reduce costs.



Strategic Outcome

- Disruptive innovation enabled
- Enabling >10MW turbine platforms commercialised
- **Maximise operational performance from existing wind farms**

UK Benefit

Low — **Medium** — High

Potential to reduce LCOE

Low — Medium — **High**

Notes: Best case if improved solutions applied before blades are installed

Case for Intervention

Low — Medium — **High**

Forecast start to finish

Now — **2020** — **2025** — 2030 — 2035 — 2040

Technology Readiness Level

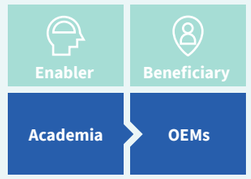
1 — 2 — 3 — 4 — **5** — **6** — **7** — **8** — **9**

Fig 4: Hydraulic gearing

POWERTRAIN > ALTERNATIVES TO GEARBOXES

Description

Use of hydraulic torque-speed converter alternatives to mechanical gearboxes. Avoids gearbox failures and facilitates use of existing scale generators. If solution will be deployed globally UK benefit will be high as design team is UK based.



Strategic Outcome

- Disruptive innovation enabled
- Enabling >10MW turbine platforms commercialised
- **Maximise operational performance from existing wind farms**

UK Benefit

Low — Medium — **High**

Potential to reduce LCOE

Low — **Medium** — High

Case for Intervention

Low — **Medium** — High

Forecast start to finish

Now — **2020** — **2025** — 2030 — 2035 — 2040

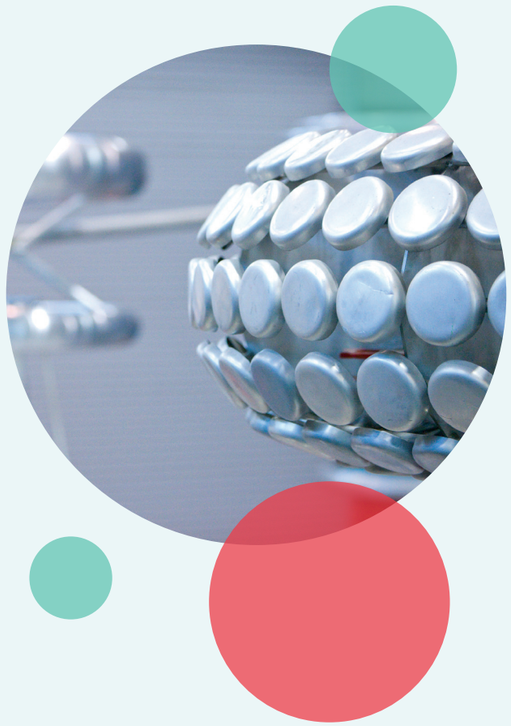
Technology Readiness Level

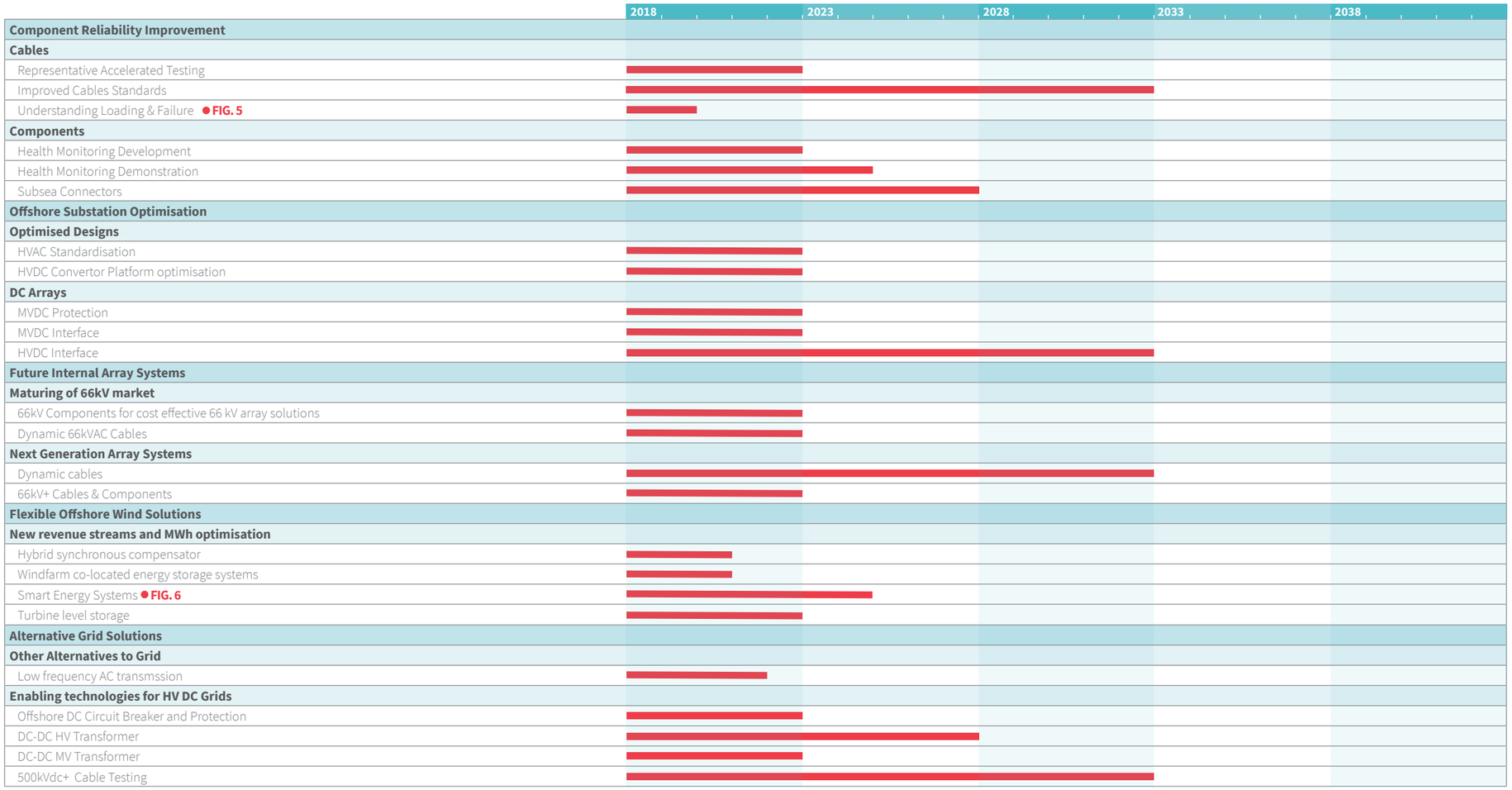
1 — 2 — **3** — **4** — **5** — 6 — 7 — 8 — 9

ELECTRICAL INFRASTRUCTURE

Moving to the next generation of electrical infrastructure that will reduce costs, increase efficiency & reliability, and facilitate greater power export capacity. This covers innovation areas in array cabling, power transmission, grid integration, and onshore & offshore substations.

Innovation areas in Electrical Infrastructure are grouped by:
Component Reliability Improvement, Offshore Substation Optimisation, Future Internal Array Systems, Flexible Offshore Wind Solutions, Alternative Grid Solutions





● FIG. 5
● FIG. 6

SUBSTRUCTURES

Innovation areas with the potential to reduce costs through the optimisation of the design, manufacture, installation, or service life of substructures. This includes optimisation of existing designs and potential disruptive concepts to the towers, foundations and transition pieces.

Innovation areas in Sub-Structures are grouped by:
Materials, Foundations, Transition Pieces, Floating Wind, Design, and Towers.

	2018	2023	2028	2033	2038
Materials					
Materials Protection					
Corrosion Protection					
SACP Gas evolution					
New Materials					
Self healing materials					
Lighter and stronger materials					
Foundations					
Novel fixed foundations					
Novel fixed foundations					
Self-installing foundations					
Barge based GBF Fabrication					
Gravity Base Foundations (GBFs)					
Monopiles					
Monopile lifetime assessment - establishing methodology ● FIG. 7					
Monopile lifetime assessment - establishing technology					
Standardisation of monopile monitoring + SHM					
Monopiles lower fabrication cost					
Pile installation noise reduction					
XL monopiles					
Optimizing jacket manufacturing					
Increased welding automation					
Industry-wide standardisation of nodes					
Real time weld inspection					
Transition Piece					
Incorporating TP into Foundations					
Floating Wind					
Achieve cost equivalent of fixed					
Achieve cost equivalent of fixed					
Port facilties for serial production					
Substructures optimised to wind turbine OEM requirements (eg loads, control)					
Access and egress for O&M					
Standardisation of concepts					
Optimised/standardised power transmission (dynamic cables and connectors)					
Consolidation in the number of designs					
Design					
Design standards					
Updated standards review					
Integration of design					
Total integrated design ● FIG. 8					
Combined WEC/WTG floating foundations					
Integrated installation of TP, foundations and tower					
Tower					
New towers constructions					
Concrete towers					
Lattice Towers					
Reduce mass of towers					
Reduce mass of tower					

SOME KEY ELEMENTS IN DETAIL

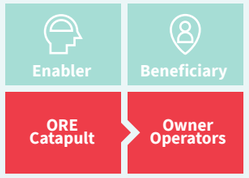
ELECTRICAL INFRASTRUCTURE

Fig 5: Understanding loading & failure of cables

COMPONENT RELIABILITY IMPROVEMENT > CABLES

Description

Tools are required to accurately forecast the likelihood of access across a wind farm site that makes account for met ocean conditions at specific turbine locations and vessel limitations. Existing tools exist as commercial offerings, but further research on disruptive, next generation tools is worthwhile.



Strategic Outcome

- Disruptive innovation enabled
- **Enabling >10MW turbine platforms commercialised**
- Maximise operational performance from existing wind farms

UK Benefit

Low | Medium | High

Potential to reduce LCOE

Low | Medium | **High**

Case for Intervention

Low | **Medium** | High

Forecast start to finish

Now — **2020** | 2025 | 2030 | 2035 | 2040

Technology Readiness Level

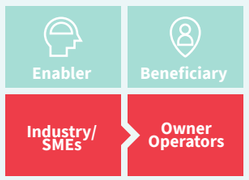
1 | 2 | 3 | 4 | **5** | **6** | **7** | 8 | 9

Fig 6: Smart energy systems

FLEXIBLE OFFSHORE WIND SOLUTIONS > NEW REVENUE STREAMS AND MWH OPTIMISATION

Description

Cyber Security and Network Automation Solutions for offshore wind. Develop standards, demonstration, etc. Pre-cursor to smart systems, and facilitator for new business models and commercial arrangements. Potential to reduce LCOE is Medium-High.



Strategic Outcome

- Disruptive innovation enabled
- Enabling >10MW turbine platforms commercialised
- **Maximise operational performance from existing wind farms**

UK Benefit

Low | **Medium** | High

Potential to reduce LCOE

Low | **Medium** | High

Case for Intervention

Low | **Medium** | High

Forecast start to finish

Now — **2020** — **2025** | 2030 | 2035 | 2040

Technology Readiness Level

1 | 2 | 3 | **4** | **5** | **6** | **7** | 8 | 9

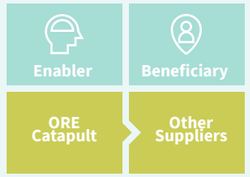
SUBSCTRUCTURES

Fig 7: Monopile lifetime assessment – establishing methodology

FOUNDATIONS > MONOPILES

Description

There are currently no standard methods for the assessment of remaining life of monopile foundations in the offshore wind industry. Such a method would enable a standardised and agreed approach for asset owners to make informed analysis as to the potential remaining operating life of the foundation and also enable the potential for life extension justification.



Strategic Outcome

- Disruptive innovation enabled
- Enabling >10MW turbine platforms commercialised
- **Maximise operational performance from existing wind farms**

UK Benefit

Low | **Medium** | High

Potential to reduce LCOE

Low | Medium | **High**

Case for Intervention

Low | Medium | **High**

Forecast start to finish

Now — **2020** — **2025** | 2030 | 2035 | 2040

Technology Readiness Level

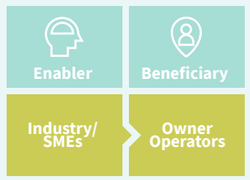
1 | 2 | 3 | **4** | **5** | **6** | 7 | 8 | 9

Fig 8: Total integrated design

DESIGN > INTEGRATION OF DESIGN

Description

Offshore wind turbines (fixed or floating) are coupled systems, however to date these have often been designed as two independent systems (a foundation and a wind turbine). This has resulted in suboptimal designs of foundations. A more open relationship between foundation designers and wind turbine OEMs can improve foundation designs, ultimately lowering the LCOE of offshore wind.



Strategic Outcome

- Disruptive innovation enabled
- **Enabling >10MW turbine platforms commercialised**
- Maximise operational performance from existing wind farms

UK Benefit

Low | Medium | **High**

Potential to reduce LCOE

Low | Medium | **High**

Notes: Optimised structure in terms of steel, construction, installation, O&M and decommissioning

Case for Intervention

Low | Medium | **High**

Notes: Currently there exists a barrier between OEMs

Forecast start to finish

Now — **2020** — **2025** | 2030 | 2035 | 2040

Technology Readiness Level

1 | 2 | 3 | 4 | **5** | **6** | **7** | **8** | **9**

CATAPULT
Offshore Renewable Energy

Innovate UK
Knowledge Transfer Network

CONTACT

Jonny Flowers
Email: info@offshorewindinnovationhub.com
Tel: +44 (0)333 004 1400

Version 1: March 2018