Strategic Research Agenda

Targeted research to unlock growth in offshore renewable energy

Engineering and Physical Sciences Research Council

Supergen
Offshore Renewable Energy

ABOUT THE SUPERGEN ORE HUB

The Supergen Offshore Renewable Energy (ORE) Hub provides ambitious research leadership to coordinate and spotlight research and innovation across offshore wind, wave and tidal energy. As a trusted voice in the ORE sector, we bring stakeholders together around a whole-system approach to energy, supporting collaboration across academia, industry and policy to enable research and innovation to drive change across the sector.

We advocate for ORE with decision makers and we communicate the urgency of change. We continue to expand our partnerships to help developers and suppliers bring new technologies into the market, while connecting research with key industry challenges.

Recognising that the next generation will be critical to building a strong, diverse and resilient sector, we train future leaders and strengthen ORE and ocean literacy within the wider public.

The determination within the Supergen ORE Hub community stems from a shared understanding that ORE is more than the cornerstone of the UK's clean energy system. It is also a powerful opportunity to build the foundations of a secure energy future, accelerate the transition to Net Zero, and ensure the benefits of that transition are felt in communities and economies across the UK.

- The Hub is a collaborative partnership between the universities of Oxford, Aberdeen, Edinburgh, Exeter, Hull, Manchester, Plymouth, Southampton, Strathclyde, and Warwick.
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Section 1: Overview

VISION

The Supergen Offshore Renewable Energy (ORE) Hub's Strategic Research Agenda (SRA) sets out research priorities to enable accelerated and enduring progress across the UK ORE sector. Developed in collaboration with the wider ORE community, it provides a consensus view on the coordinated research effort needed to underpin a secure and sustainable energy future for economic and societal benefit across the UK.

INTRODUCTION

Competitive Advantage through Targeted Research

A decade ago, the scale of the opportunity for ORE technologies in transforming the UK's energy system was still a matter of debate. That is no longer the case. Today, there is strong agreement within UK energy policymaking that innovative ORE technologies will play a long-term role in delivering a secure, resilient, and sustainable energy future, with offshore wind a major part of the industrial strategy, contracts awarded for tidal stream projects and wave energy receiving research support.

The Opportunity and Challenge

However, a future where the UK ORE sector is led by UK developers and companies is far from guaranteed. To ensure that we maximise benefit from our own energy transition, the UK ORE sector will need to navigate a complex set of interconnected challenges. Maintaining public confidence and a social licence for deployment, developing competitive domestic supply chains capable of retaining jobs and economic value, deploying projects in the right locations and at the appropriate pace, and ensuring that the transition is delivered in a cost-effective manner are all critical to success.

Foundations for Competitiveness

For the UK, meeting and overcoming these challenges will require more than just the deployment of today's technologies. It will depend upon a continuous pipeline of disruptive and innovative technologies, solutions and capabilities, with the potential to reduce costs, improve performance and strengthen industrial competitiveness. Ensuring that this pipeline remains strong requires a clear and coordinated approach to both identifying and addressing the underpinning research challenges that will shape the future development of the ORE sector.

Without a broad base of underpinning research feeding this innovation pipeline, the UK's ability to maintain leadership in the ORE sector and maximise the value of future deployment will be significantly constrained.

Strategic Priorities

The challenge for policymakers is therefore no longer simply whether to support underpinning research and innovation across the ORE sector, but how that support can be directed most effectively. While all ORE technologies require continued research and innovation, they are not progressing across their shared development pathway at the same pace. Offshore wind, tidal stream and wave energy each occupy different stages of technological and commercial maturity, face distinct barriers to deployment, and require different forms of intervention to accelerate progress. Maximising the value of future investment therefore requires a coordinated approach that can identify specific cross-cutting research priorities. Additionally, the uncertainties associated with this early-stage research are unsuitable for private investment alone. Targeted public support is therefore essential to generate the disruptive ideas, evidence and capabilities that industry can later develop, demonstrate and commercialise.

Ultimately, the role of the UK's academic and research community extends beyond the delivery of individual research projects. As a collaborative ecosystem, it is uniquely positioned to provide the evidence, insight and strategic oversight required to ensure that research effort and investment are directed towards the areas capable of delivering the greatest long-term impact.

By identifying shared challenges and aligning activities with the evolving needs of industry and policymakers, the research community can help maximise the effectiveness of future innovation support.

In the long-term, disruptive innovation is the engine that will drive the future development and competitiveness of the UK ORE sector. This Strategic Research Agenda (SRA) provides a framework for coordinating activities to fuel that engine, ensuring that the innovations needed to overcome tomorrow's challenges begin with the research undertaken today.

> "**The UK's emerging offshore renewable energy sector, will be shaped by the decisions we make today.** Strategic research provides the foundation for the innovations, capabilities and industries that will power the next phase of growth. By aligning our efforts around the shared priorities outlined in this report, we can accelerate progress, strengthen our global competitiveness and ensure that the benefits of the energy transition are anchored here in the UK."
>
> **Tim Pick, Offshore Wind Growth Partnership Chair**

Experimental Testing, University of Plymouth

WHY STRATEGIC RESEARCH MATTERS

The Foundation of Innovation

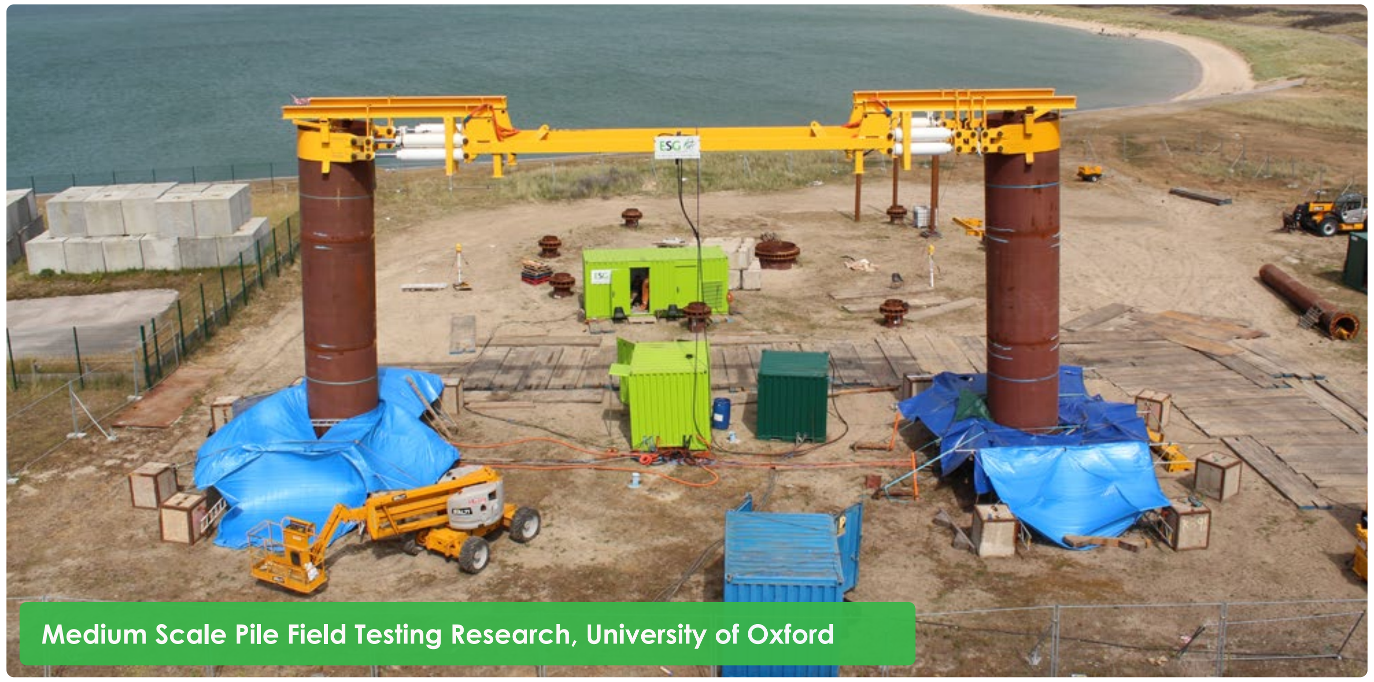
Coordinating research effort around shared strategic priorities is essential if the UK is to convert world-leading academic excellence into sustained innovation, industrial competitiveness and long-term sector growth. The UK ORE sector benefits from a range of established innovation support mechanisms, including the Energy Innovation Needs Assessments (EINAs), which help identify technology innovation priorities. At the European level, several Strategic Research and Innovation Agendas (SRIAs) provide long-term frameworks for coordinating research and innovation activities across key sectors, including offshore wind and ocean energy.

The Need for a Framework for Underpinning Research

However, while these frameworks provide valuable guidance on innovation requirements, **there is currently no equivalent UK ORE sector-wide report** dedicated to identifying and coordinating the underpinning research challenges that will shape the long-term development of the sector.

> **The absence of such a report highlights a notable gap within the UK's innovation ecosystem.**

To address this gap, and support both innovation and accelerated sector growth, the Supergen ORE Hub SRA identifies the underpinning research priorities required to enable disruptive, cross-cutting and long-term progress across the UK ORE sector. In doing so, it provides a strategic framework for coordinating research activity, informing investment decisions and aligning future research efforts with the evolving needs of industry, policymakers and wider society.



Medium Scale Pile Field Testing Research, University of Oxford

Primary Audience and Value of the SRA

The SRA is intended to serve as a valuable resource for a broad range of stakeholders across the UK ORE sector. However, it is primarily designed to support two key audiences:

- First, it provides innovation funders and funding organisations with the evidence base required to design, target and coordinate future research and innovation calls around the identified priority areas within the UK ORE sector. In doing so, it aims to support more strategic investment decisions and encourage the development of coherent funding pathways that can accelerate progress from research through to commercialisation.
- Second, it provides the wider research community with greater visibility of the priority challenges facing the sector. By establishing a shared understanding of future research needs, the SRA can help align activities across the innovation ecosystem and ensure that future interventions are targeted towards areas capable of delivering the greatest long-term impact.

In addition to catering for these primary target audiences, the SRA will also:

- Enable policy makers to create a connected pathway of research, innovation and commercialisation interventions to ensure climate and economic ambitions are achieved.
- Assist industry to combine efforts, leverage existing research and access research expertise and facilities.

> "**Looking back on what the UK's ORE research community has achieved, it is clear we have made significant progress.** We should feel proud of our work supporting the UK's role as a global leader in ORE innovation and deployment. The Supergen ORE Hub will continue to champion collaboration and coordination, sharpening our focus to ensure that underpinning research and forward-thinking strategy drive sustained innovation and accelerated delivery."
>
> Professor Deborah Greaves, OBE FREng, Supergen ORE Hub Director

POSITIONING THE SRA WITHIN THE UK ENERGY POLICY LANDSCAPE

Here we identify the primary ambitions driving the development of UK energy policy and outline how these influence the positioning of the resulting Supergen ORE policy landscape.

The UK's Clean Energy and Economic Growth Ambitions

The purpose of the SRA is to ensure that future research activities are aligned with the strategic objectives that will shape the future development of the UK ORE sector. At the highest level, the current direction of travel for the UK ORE sector is being shaped by an urgent desire to deliver on two closely connected national ambitions:

Clean Energy

First, the UK must take urgent steps to lower its Green House Gas (GHG) emissions, adhering to its legally mandated goal to achieve Net-Zero by 2050 [1], the shorter-term aim of a clean power system by 2030 [2] and the associated energy security. The realisation of these goals, which are vital to mitigating the worst extremes of the ongoing climate crisis, will rely heavily on the accelerated delivery of a national decarbonised energy system.

Economic Growth

At the same time, the UK must also actively seek new sources of clean and competitive economic growth. In doing so it must focus on strategic sectors that can translate their value into tangible benefits, realised through improved socioeconomic returns and high-value job creation across the country [3]

Ambition into Action

These ambitions should not and must not be pursued in isolation. They are mutually reinforcing, critical national missions, as illustrated in Figure 1. The UK's current national policy landscape relevant to ORE is structured around two central policy anchors: the *UK's Modern Industrial Strategy* [3], which frames the UK's long-term economic growth agenda, and the *Clean Power 2030 Action Plan* [2], which frames the near-term clean energy delivery agenda.

The UK's Modern Industrial Strategy establishes the clearest articulation for a national economic growth mission, while the *Clean Power 2030 Action Plan* details an ambitious but achievable route to a future where this growth is underpinned by a decarbonised electricity system. The future development of the UK ORE sector sits at the intersection of these two ambitions, with the sector expected to contribute simultaneously to clean energy delivery, industrial competitiveness and economic prosperity.

Figure 1. The UK ambitions for economic growth and clean energy are underpinned by the ORE sector.

These wider policy frameworks establish a clear strategic rationale for the continued development of the UK ORE sector. The *Modern Industrial Strategy* [3] identifies clean energy industries as a source of long-term economic growth, while the *Clean Power 2030 Action Plan* [2] establishes an urgent need for the accelerated deployment of these technologies.

> ORE sits at the intersection of clean energy and economic growth.

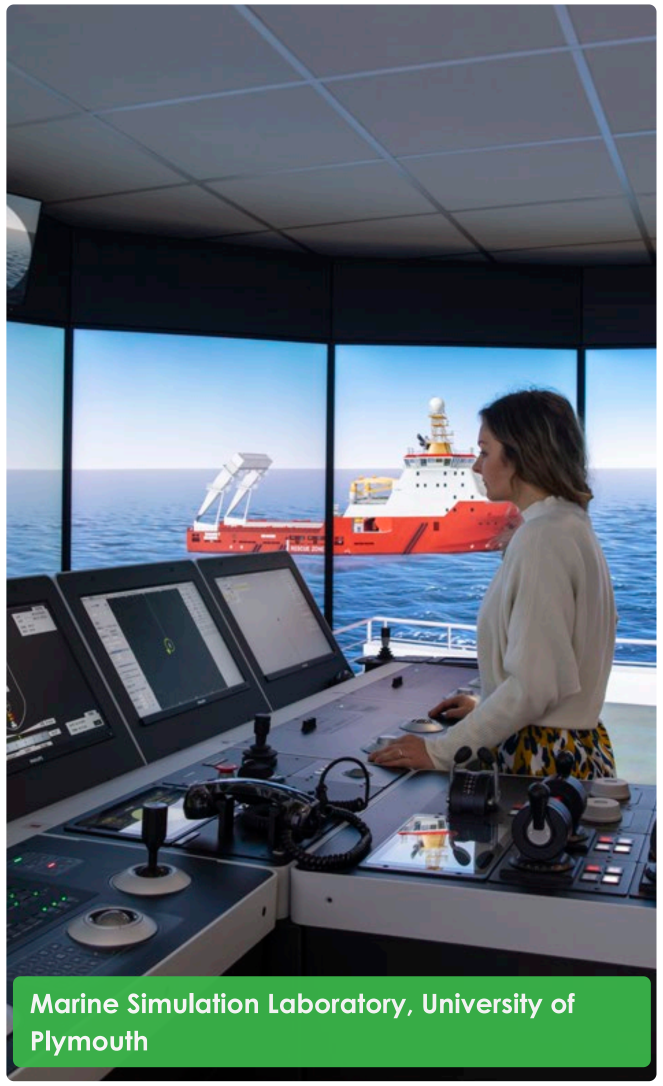
Consequently, the future success of the UK ORE sector is no longer solely a matter of energy policy. It has become intrinsically linked to the delivery of wider national objectives relating to economic growth, industrial resilience, energy security and Net Zero. Continued advances across the ORE sector therefore represents not only an opportunity to decarbonise the UK energy system, but also a pathway through which the UK can capture greater economic value from the global Net Zero transition.

The underpinning research challenges identified within this SRA are intended to help ensure that future research and innovation activities contribute directly to the development of ORE technology and the UK ORE sector as a whole, while also respecting the need to protect nature.

Supergen ORE Hub Policy Evidence Base

The national ambitions outlined in the previous section are already supported by a growing body of policy guidance reports developed by the Supergen ORE Hub. Collectively, these reports examine the role that the ORE sector can play in delivering the UK's clean energy, economic growth and industrial competitiveness objectives, while identifying the actions required to maximise the sector's contribution.

Key publications within the Supergen ORE hub landscape include:



Marine Simulation Laboratory, University of Plymouth

- *What is the value of innovative offshore renewable energy deployment to the UK economy?* – which quantifies the potential socioeconomic benefits associated with the deployment of innovative ORE technologies. [4]
- *Disruptive Innovation and Industrial Modernisation* - which identifies the innovation and industrial capabilities required to establish a competitive UK ORE sector and capture greater value from the energy transition. [5]
- *ORE Outlook 2040* - which explores potential future development pathways for the UK ORE sector and the opportunities they present for a just, sustainable and secure energy transition. [6]

These reports identify the opportunities and strategies required to support ORE sector growth. By identifying the research challenges required to enable future technological, industrial and commercial progress, the SRA provides the research foundation upon which the wider Supergen ORE Hub policy portfolio is built.

Potential Economic Prize

The Supergen ORE report *What is the value of innovative ORE deployment to the UK economy?* [4] outlines the potential socioeconomic benefits of highly-innovative ORE technologies, such as floating offshore wind, tidal stream and wave energy.

This report looks beyond the shorter-term timelines associated with the offshore wind sector's *Industrial Growth Plan* [7] and the *Clean Power 2030 Action Plan* [2], towards the potential energy system role to be played by

Figure 2. Supergen ORE Hub evidence base for sector growth

these innovative ORE technologies, all of which are currently at different stages of commercial maturity.

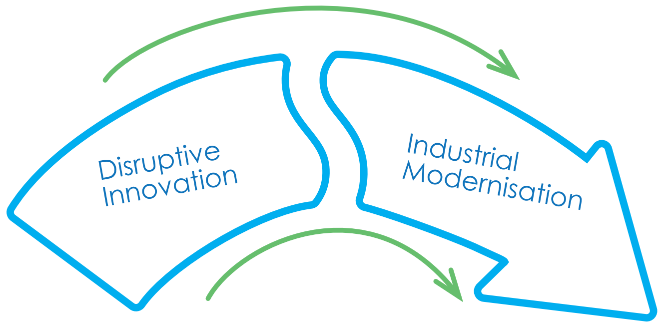
Its primary findings show that the deployment of 45 GW of floating offshore wind, 6 GW of tidal stream, and 6 GW of wave energy in UK waters by 2050 could generate between £18bn and £41bn of GVA and provide over 166,000 FTE jobs in 2050.

Delivering Disruptive Innovation and Industrial Modernisation

The Supergen ORE Hub *Disruptive Innovation and Industrial Modernisation* report [5] examines how Disruptive Innovation and Industrial Modernisation can strengthen the UK's ORE supply chain competitiveness. It explores how the UK can move beyond incremental growth to adopt a Disrupt and Modernise approach, enabling a Leapfrogging Transition in the development and manufacture of high-value ORE technologies, subsystems and components.

The Leapfrogging Transition

The UK has the opportunity not only to establish itself as a leading location for ORE innovation, but also to become the nation synonymous with translating advances in technology, materials and manufacturing processes into competitive, scalable industrial production.



Projecting forward to 2040

The Supergen ORE Hub report - ORE Outlook 2040 [6] - summarises the current and future contribution of ORE to the 2050 Net Zero target, using 2040 as a key milestone on this journey. It highlights the implications of the ORE deployment levels required by 2040, which are explored through four lenses: (i) planning and consenting, (ii) people, (iii) supply chain and (iv) infrastructure and grid.

People

Current rates of sector workforce growth will not meet projected requirements. Research and Innovation can reduce the scale of the workforce challenge by boosting productivity and integrating industry 4.0 advances.

Planning & Consenting

Offshore renewable projects can take up to 15 years to reach operation. Research and innovation can accelerate delivery through adaptive management, improved data and understanding of ocean interactions.

Infrastructure & Grid

Decade-long lead times for major infrastructure and grid upgrades require immediate action. Research and innovation can ease this challenge by reducing infrastructure requirements and accelerating planning and construction.

Supply Chain

Research and innovation underpin a competitive supply chain, securing economic value, technological leadership, and a faster energy transition. The Offshore Wind Industrial Growth Plan sets a shared vision [7].

Across these four areas it clear that a business-as-usual approach cannot achieve the level of upscaling that is required to make the UK's ORE sector a commercial success. Instead, sustained and proactive support for research and innovation is required to deliver a step-change in both technology and supply chain capabilities.

The scale of the transformation that must be achieved by 2040 is summarised using three simple measures:

×7 volume by 2040 — **Seven times the volume of current ORE capacity**

×4 rate to 2040 — **Four times the rate of ORE building we see today**

×6 people by 2040 — **Six times the current ORE workforce**

The ORE Outlook 2040 report [6] shows that Research and Innovation are vital to enable the ORE growth required for the sector to become a commercial success.

The Rationale for Strategic Guidance for Underpinning Research

As this overview of the existing Supergen ORE Hub reports demonstrates, sustained investment in underpinning research and innovation is fundamental to unlocking the socio-economic value of the UK ORE sector. This same support is also essential to provide the foundation for scaling deployment to enable a meaningful contribution by 2040, while maintaining a pipeline of disruptive innovations that strengthens the UK's long-term competitiveness.

To ensure the UK's continued competitiveness this Supergen ORE Hub Strategic Research Agenda (SRA) will identify a pipeline of essential underpinning research that will enable cross-cutting and disruptive progress in the UK ORE sector.

Section 2: Developing the SRA

GUIDING ENGAGEMENT ACROSS THE UK INNOVATION LANDSCAPE

The UK Innovation Funding Landscape

While the previous sections have demonstrated how national ambitions for clean energy and economic growth can help inform the strategic direction of the UK offshore renewable energy (ORE) sector, they also highlight a broader need for coordination across underpinning research activities. However, identifying research priorities alone is not sufficient. To generate impact, these priorities must be understood within the wider innovation ecosystem responsible for transforming research outputs into economic value.

This presents an additional challenge for the sector. The UK innovation landscape comprises a diverse range of organisations, funding mechanisms and support programmes, each operating with different objectives, responsibilities and timescales. Understanding how these actors interact is essential when identifying research priorities, as the impact of research depends not only on what is funded, but also on how effectively it can progress through the wider innovation ecosystem.

At the earliest stages of the innovation pathway, organisations such as Supergen ORE Hub and UKRI support the underpinning research activities that generate new knowledge, ideas and technological concepts. These outputs are subsequently advanced through organisations that are focused on translating the work of the research community into applied innovation, technology development and demonstration. From there, larger-scale funding bodies help to de-risk emerging technologies and accelerate their progression towards commercial deployment.

Within this landscape, UK Government support performs a distinct and critical role. While later-stage technology development and commercial deployment can increasingly draw upon private investment, the earliest stages of innovation often involve levels of technical uncertainty and commercial risk that are difficult for industry to support alone. Public investment therefore plays a vital role in creating the conditions from which novel ideas, concepts and technologies can emerge.

> **This early-stage support is one of the most impactful interventions available to UK Government.** By investing in underpinning research, they help create the knowledge base from which disruptive methods and technologies can develop. These innovations subsequently flow through the wider innovation ecosystem, where they can be refined, demonstrated and ultimately deployed at commercial scale.

The sustained generation of disruptive innovation, fuelled by underpinning research, is fundamental to UK competitiveness. It enables the sector to move beyond incremental improvement, establish new sources of technological advantage and strengthen the UK's position within emerging ORE markets. Crucially, it provides an opportunity for the UK to help define the next generation of technologies, components and supply chains, rather than simply responding to innovations developed elsewhere.

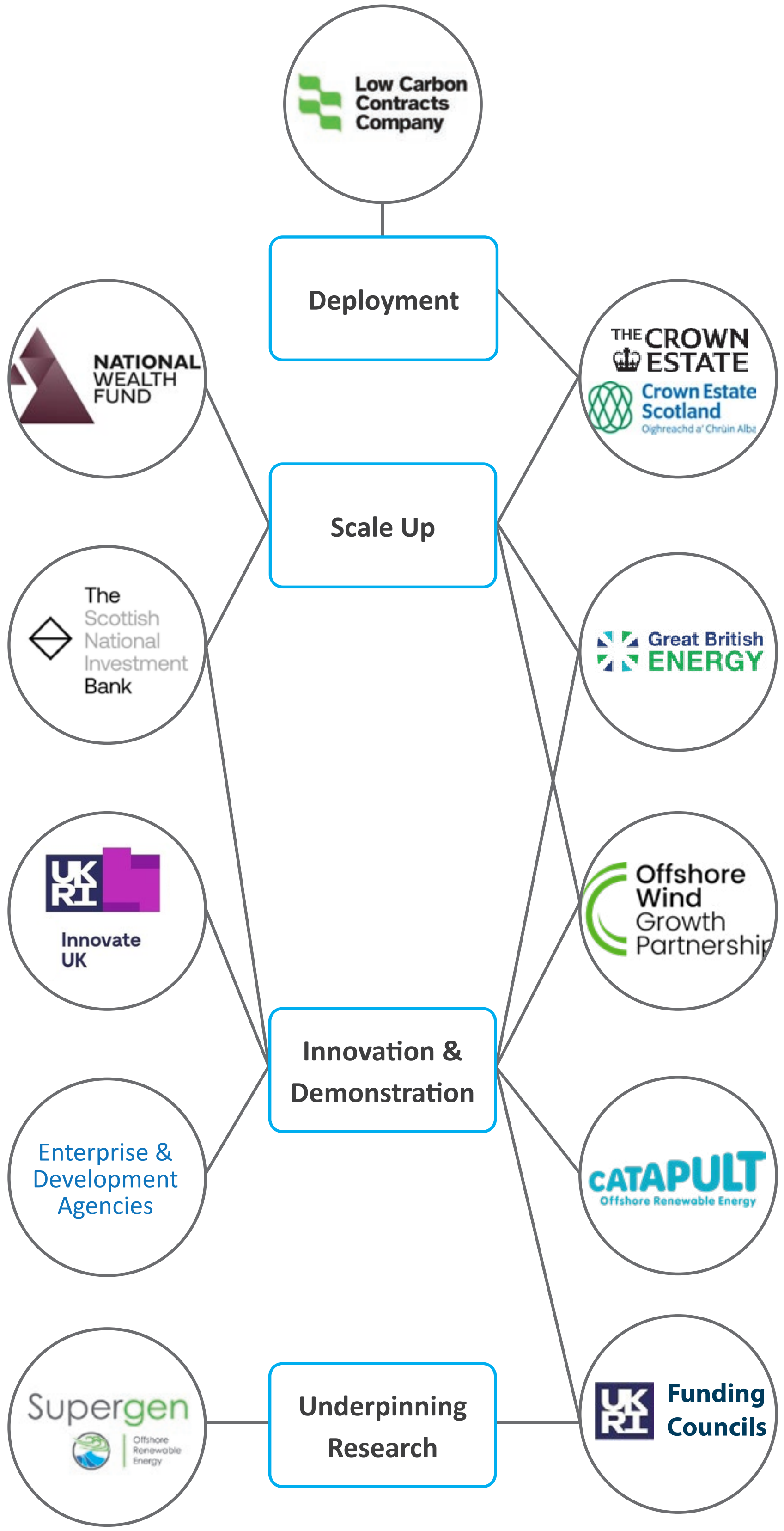


Figure 3. The UK innovation Funding Landscape

COMMUNITY-LED CONSULTATION

The Supergen ORE Hub SRA is founded upon a community-led approach to identifying and prioritising the research challenges that will shape the future development of the UK ORE sector. As such, the priority areas and research challenges are the product of an extensive consultation process undertaken throughout 2025 and 2026, involving national and international academic experts, industry stakeholders and policymakers (Figure 4).

This process was further strengthened through dedicated engagement with the teams responsible for developing the *Industrial Growth Plan* [7], ensuring that the identified research priorities reflect both emerging technological challenges and wider industrial development objectives.

Across these activities, a broad range of research topics, technology needs and sector-wide challenges were reviewed and discussed. The outcome was a collective view of the underpinning research areas considered most critical to supporting future innovation, competitiveness and growth across the core energy generation technologies that comprise the UK ORE sector.


The Supergen ORE Hub Early Career Forum 2025

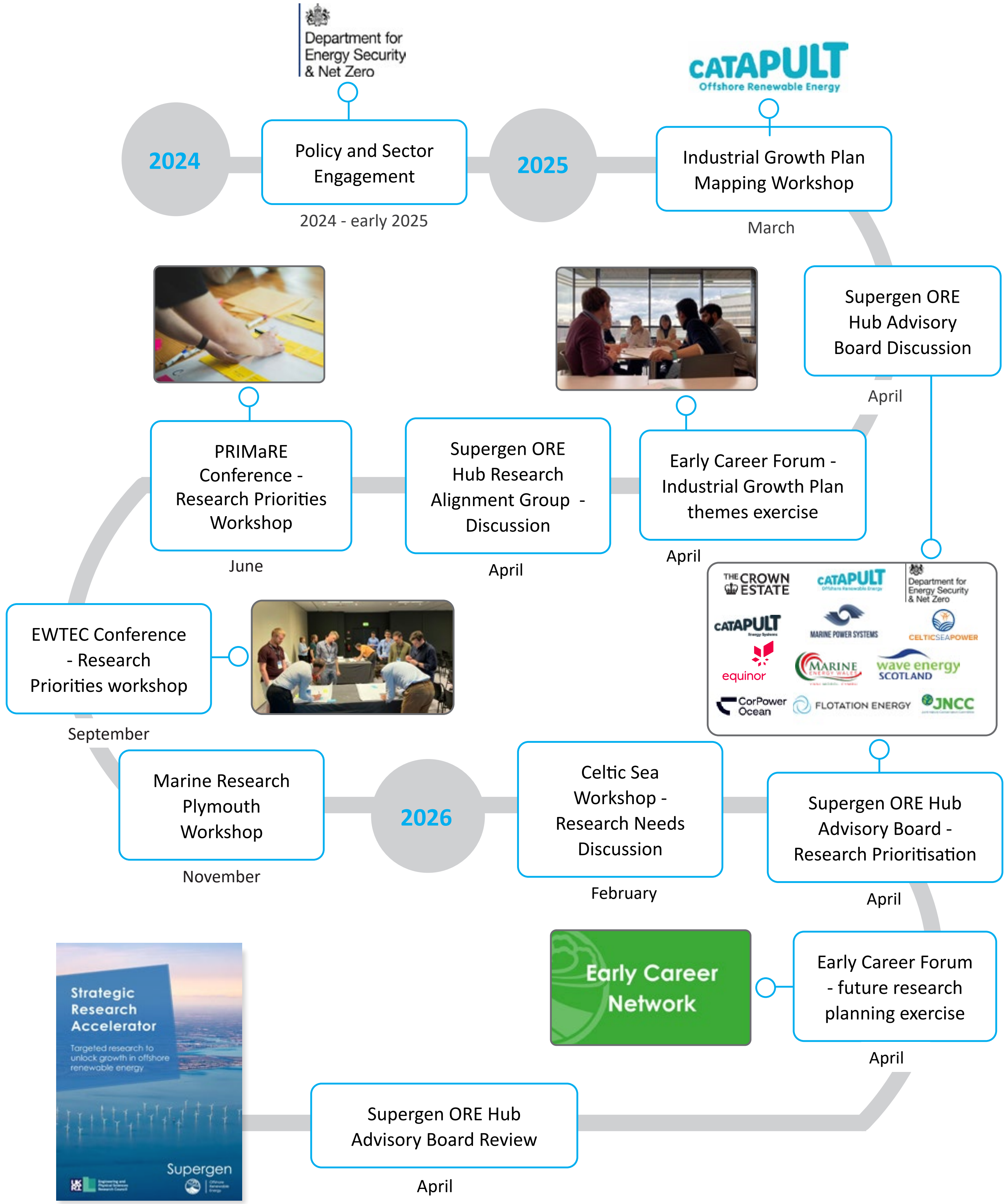


Figure 4. Community engagement on Research Priorities

RESEARCH PRIORITISATION

Common Areas and Maximum Impact

In this Supergen ORE Hub Strategic Research Agenda, we respond to the need for strategic guidance for underpinning research by synthesising the key research challenges of the next 5 years and beyond. The **Research Challenges** can be viewed through the lens of **Research Grand Challenges** that reflect advances in new technology and opportunities in innovation, such as AI and new materials, and respond to drivers for engineering solutions, such as sustainability, acceleration, security and economic growth. The research challenges are also selected to address the required advances in subsystems and enabling capabilities (Figure 5), and are organised into four cross-cutting **Industry Priority Areas** that reflect the shared needs across the ORE sector.

Figure 5. Cross-cutting technology subsystems and industry priority areas

Although offshore wind, tidal stream and wave energy systems occupy different stages of technological and commercial maturity, they rely upon many common technology subsystems and enabling capabilities, numbered 1-7 in Figure 5. As a result, many of the barriers to future growth faced by any one technology are shared across the wider sector. Continued progress will require advances in the areas spanning these common subsystems and enabling capabilities, including next-generation components and subsystems, large-scale manufacturing and industrialisation, electrical infrastructure, and the processes and services required to deploy, operate and maintain technologies at scale.

Research challenges are selected for maximum impact on the basis of their disruptive/leapfrogging, cross-cutting and accelerative potential:

Disruptive/leapfrogging

Research that is truly disruptive and not just incremental, that enables a step change in either UK competitiveness and growth or the significant acceleration of a process. This approach should specifically target ORE technologies with the potential to disrupt the existing ORE market and with a high suitability to be manufactured economically and at scale in a modernised supply chain.

Cross-cutting

Research that leverages synergies across ORE, enabling benefits spanning technologies, companies and sectors. Floating offshore wind and floating tidal designs have benefited from knowledge generated in the wave energy sector; first commercial projects in tidal stream and emerging wave energy sector benefit from the technology development pathway pioneered by offshore wind; and all sectors benefit from shared understanding of operating within and interacting with the marine and offshore environment.

Accelerative

Research that tackles critical upscaling ORE bottlenecks areas, including consenting, installation, manufacturing and grid connection required to meet Net Zero targets and achieve UK competitiveness and growth.

Section 3: Research Challenges

RESEARCH GRAND CHALLENGES

This section introduces the research grand challenges and the industry priority areas, outlines the framework within which they sit, and then describes each research challenge in detail.

Sustainability: materials

Next generation offshore renewable energy (ORE) systems to achieve sustainable lifecycles with reduced reliance on critical raw materials

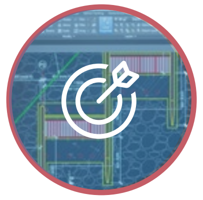
New materials and processes for sustainable manufacture will enable circular economy aspirations in ORE infrastructure and subsystems (A2). New techniques for safe decommissioning and the reuse of infrastructure and components will be needed (A4), alongside advances in sensor technology, AI and data analysis for predictive maintenance, and novel materials and designs for electrical systems (C1, D1).

Sustainability: environment

Multi-disciplinary co-design of ORE systems for engineering and ecology

New sensing, autonomous data collection and AI-enhanced analysis enable the development of efficient and effective observation and modelling tools that combine engineering with environmental and ecosystem inputs and outputs needed for ORE nature-based design (D2, D3).

University of Plymouth, The COAST Laboratory



Confidence in advances

Modelling & predictive capabilities that accelerate innovations to reduce reliance on large scale real-world operational experience (number & duration)

Improvements in modelling capability and coupling between scales, computing architectures and accelerations through ML can vastly increase the scope and ambition of numerical predictions, but need careful validation and uncertainty quantification. Prediction of environmental conditions within arrays enables confident design and resource analysis (B2); fully coupled models integrate fluid loadings, structural responses, motion responses and soil responses of individual systems (B3, B4); and farm to farm scale modelling enables yield and revenue prediction (D5).

Acceleration through technology

Automation to improve productivity in manufacture, installation, operations and maintenance

Advances in AI, automation and robotics in advanced manufacturing can transform the potential for industrialised manufacture and assembly (A1). Autonomous systems and real-time modelling tools in the marine environment improve the safety of inspection and maintenance operations and optimise logistics (D4).

Commoditisation through standards

Standardisation of ORE systems and integration into modernised energy grids

Exploring novel approaches and new designs for PTO systems in ORE and for deeper water foundations, such as floating and hybrid systems, will generate new lower cost solutions (A3, B1). Whole system approaches for energy systems integrate ORE production with storage to balance demand, and consider security and resilience of energy infrastructure to cyber and hostile threats (C2).

INDUSTRY PRIORITY AREAS

The research challenges apply to all three ORE technologies: offshore wind, tidal stream and wave energy. There are 15 individual research challenges, grouped into four high level industry priority areas.

A. Next Generation Technologies/ Subsystems

Here we consider manufacturing processes and materials for the sustainable use of materials and enable circular use of components and decommissioning for ORE. We develop next generation systems for power take-off (PTO) and step change innovations, including multi-disciplinary testing, needed to de-risk and achieve the cost reduction that is critical for emerging technologies in tidal stream and wave energy, and to secure a greater share of manufacturing in the UK for offshore wind.

B. Industrialised Foundations and Substructures

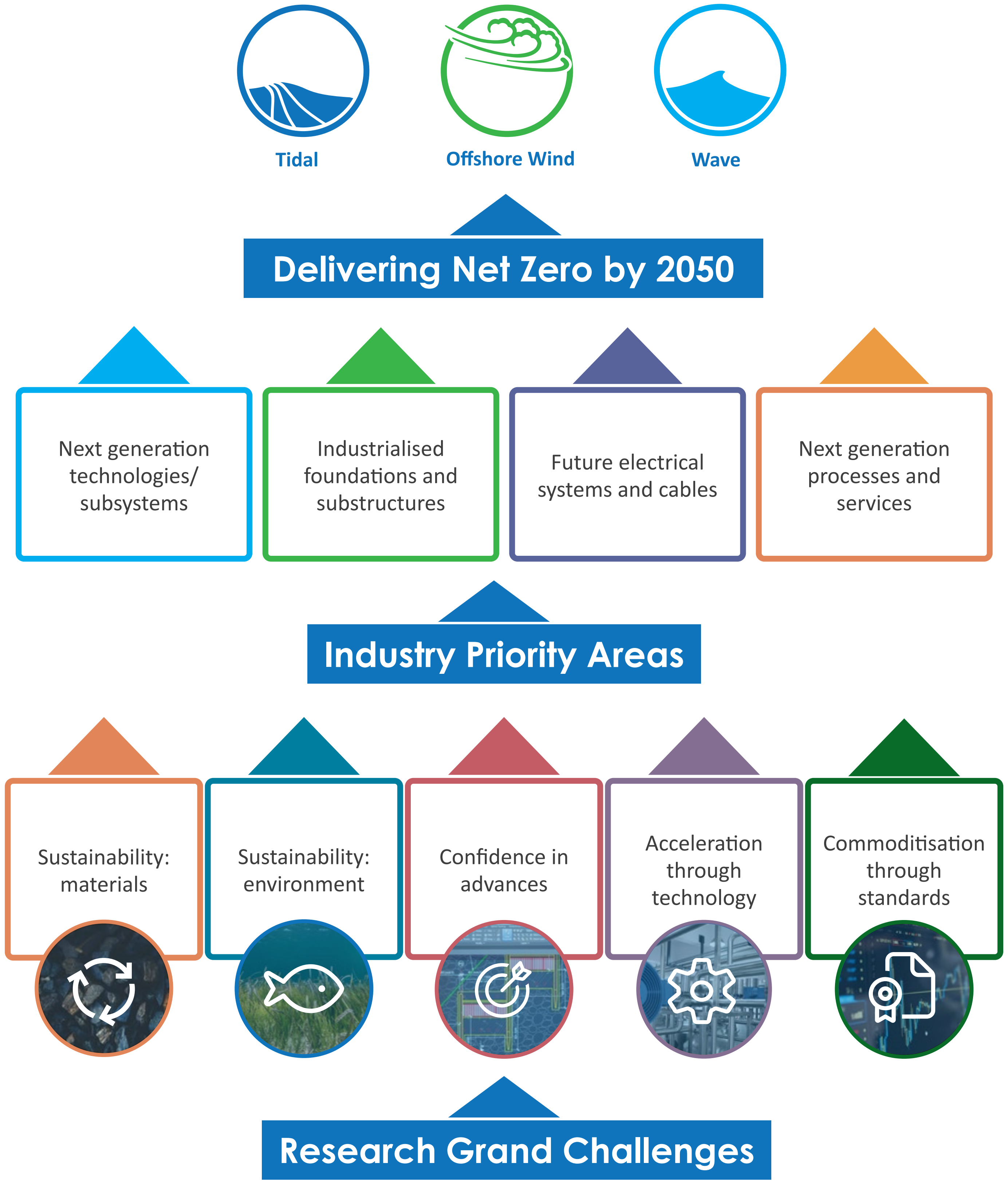
High volume manufacturing and installation of ORE foundations and substructures will be needed over the next 5, 10 and 20 years to deliver on planned expansion of offshore wind and the first commercial-scale tidal stream projects. The new frontier for offshore wind is in deeper water and so hybrid and floating solutions will be needed. Tidal stream and wave energy need further proving of reliable performance to de-risk and secure investment for their development to commercial-scale. This will need underpinning research to enable reliable predictive tools validated using experiment and field data. Progress in the use of AI and automation is enabling advanced manufacturing, marine autonomous platforms for operations, inspection and data collection and optimisation of design and operation.

C. Future Electrical Systems and Cables

Research underpinning the future electrical cables design, manufacture, strategic operation and grid integration will develop new modelling tools able to combine mechanical, electrical and thermal interaction and design. Sensor systems for continuous monitoring and use of new materials and processes to enable circular design and optimised performance of cables and components. Strategic basin scale design and energy system integration will inform future planning and operation.

D. Next Generation Processes and Services

Technical innovation in design, operation and optimisation of ORE systems is essential to achieve UK Government ambitions for energy security, economic growth and Net Zero goals. Underpinning research needed includes co-design of ORE systems and projects for engineering and ecosystem optimisation, with nature-based solutions at array and basin scale, within long term climate scenarios. Progress in AI and automation will help here in enabling the development of autonomous systems for data collection and inspection and monitoring systems for through life predictive maintenance tools.



Academic research is essential to underpinning ORE sector success. The Research that has been undertaken in recent years is having significant impact on the sector now, leading to a better understanding of current and future environmental resources and interactions, greater confidence in modelling tools and design methods, and new processes and technical solutions. The strategic research that we undertake over the next 5 years will help unlock industry priorities, as well as developing the skilled workforce of the future.

Research Grand Challenges

Sustainability: materials

Next generation ORE systems to achieve sustainable lifecycles with reduced reliance on critical raw materials

Sustainability: environment

Multi-disciplinary co-design of ORE systems for engineering and ecology

Confidence in advances

Modelling & predictive capabilities that accelerate innovations to reduce reliance on large scale real-world operational experience

Acceleration through technology

Automation to improve productivity in manufacture, installation, operations and maintenance

Commoditisation through standards

Standardisation of ORE systems and integration into modernised energy grids

Research Challenges

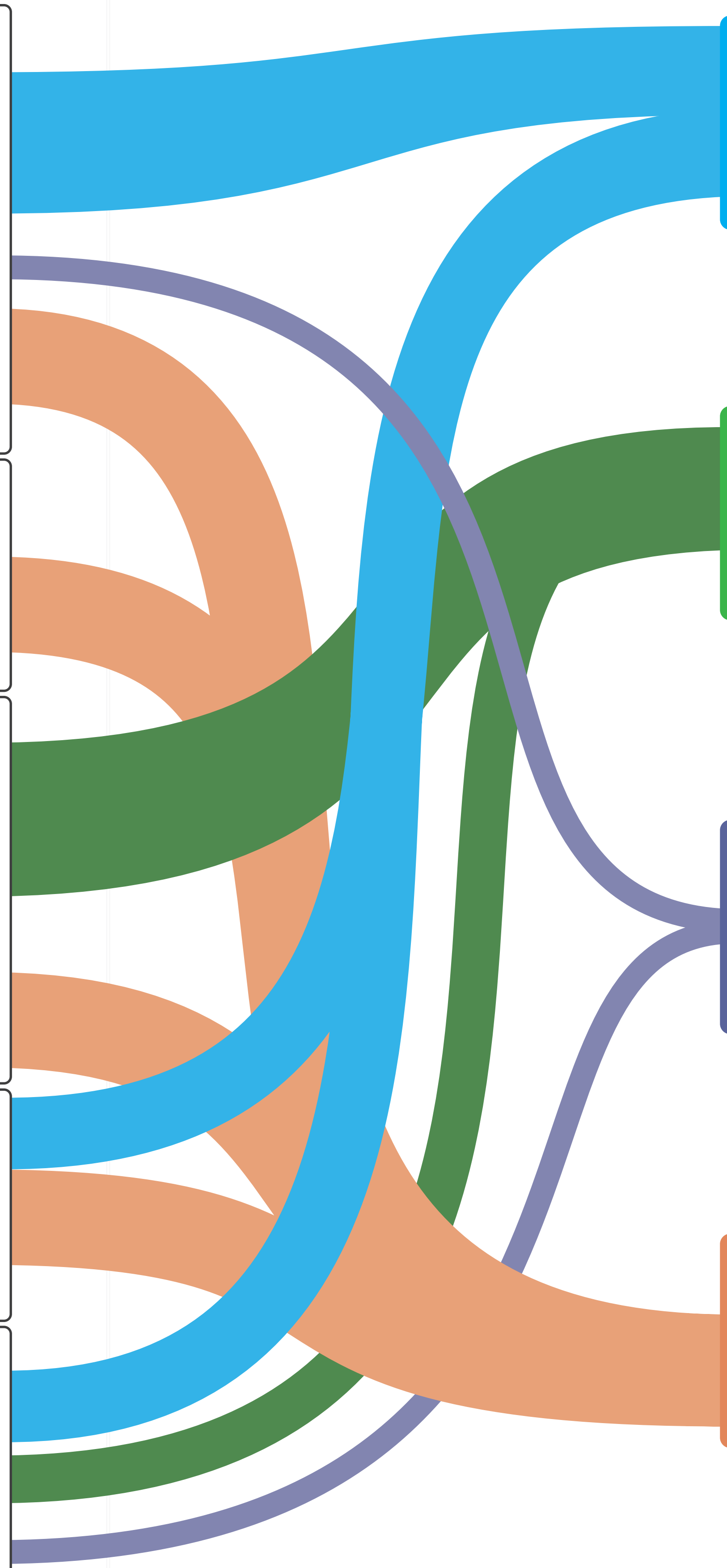
A.2: Develop & demonstrate materials and processes for sustainable manufacture, to enable circular use of ORE components
A.4: Develop decommissioning & repowering capabilities to sustain generation from existing ORE sites & improve sectoral circularity and sustainability.
C.1: Novel materials & designs for offshore cables & electrical components to improve performance, reliability and circularity.
D.1: Improve condition monitoring / instrumentation systems to enable predictive maintenance planning & end of life decisions.

D.2: Integrate observation, modelling and forecasting of engineered ORE systems, metocean conditions & ecosystems to optimise design, operation and siting.
D.3: Develop novel nature-based solutions to maximise environmental benefits of ORE.

B.2 Prediction of operating and extreme conditions to improve design of systems in arrays.
B.3: Develop and validate physics-based engineering models to improve system design.
B.4. Integrate foundation models & site characterisation to unlock design innovations & shorten development timelines.
D.5 Advance & validate ORE farm performance & yield prediction to ensure confidence in revenue predictions over operating life in an evolving climate.

A.1: Advance manufacturing, assembly & installation processes to enable ORE scale-up.
D.4: Develop autonomous systems & real-time modelling tools to optimise safety & efficiency of maritime logistics, offshore asset & project lifecycle activities.

A.3: Next generation PTO systems for ORE applications to improve performance & reduce cost.
B.1 Develop innovative seabed connection systems to enable access to a wider range of ORE resources.
C.2: Develop whole system approaches for energy systems integration & security to improve ORE utilisation & reduce infrastructure costs.



Industry Priority Areas

Next generation technologies/ subsystems

Industrialised foundations and substructures

Future electrical systems and cables

Next generation processes and services

RESEARCH CHALLENGES

Guiding UK Research and Innovation towards High-Impact Challenges

In consultation with stakeholders across the sector, these research challenges have been identified as having the greatest potential for impact. They sit within four industry priority areas and are disruptive, accelerative, and reach across offshore wind, tidal stream and wave energy.

Each Research Challenge below links to a description of the challenge, the underpinning research required, and how it can generate impact for technology development and for the UK.

A. Next Generation Technologies/Subsystems

A1 Advance manufacturing, assembly and installation processes to enable ORE scale-up
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A2 Develop and demonstrate materials and processes for sustainable manufacture, to enable circular use of ORE components.
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A3 Next generation PTO systems for ORE applications to improve performance and reduce cost.
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A4 Develop decommissioning and repowering capabilities to sustain generation from existing ORE sites and improve sectoral circularity and sustainability.
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B. Industrialised Foundations and Substructures

B1 Develop innovative seabed connection systems to enable access to a wider range of ORE resources.
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B2 Prediction of operating and extreme conditions to improve design of systems in arrays.
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B3 Develop validated physics-based coupled models to improve system design.
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B4 Integrate foundation models and site characterisation to unlock design innovations and shorten development timelines.
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C. Future Electrical Systems & Cables

C1 Novel materials and designs for offshore cables and electrical components to improve performance, reliability and circularity.
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C2 Develop whole system approaches for energy systems integration and security to improve ORE utilisation and reduce infrastructure costs.
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D. Next Generation Processes and Services

D1 Improve condition monitoring/ instrumentation systems to enable predictive maintenance planning and end of life decisions.
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D2 Integrate observation, modelling and forecasting of engineered ORE systems, metocean conditions and ecosystems to optimise design, operation and siting.
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D3 Develop novel nature-based solutions to maximise environmental benefits of ORE.
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D4 Develop autonomous systems and real-time modelling tools to optimise safety and efficiency of maritime logistics, offshore asset and project lifecycle activities.
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D5 Advance and validate ORE farm performance and yield prediction to ensure confidence in revenue predictions over operating life in an evolving climate.
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A.1: Advance manufacturing, assembly and installation processes to enable ORE scale-up

Context

Manufacturing, assembly and installation processes for ORE devices remain largely bespoke and labour-intensive. Most ORE technologies are still produced at relatively low volumes, using manufacturing approaches adapted from complementary sectors such as offshore engineering, shipbuilding or through prototype-scale fabrication rather than utilising purpose-designed industrial production systems. While these approaches have supported early-stage technology development and demonstration, they are not compatible with the levels of cost reduction and production scale required for commercial deployment. Composite materials are widely adopted for offshore wind turbine blades, but the manufacturing processes used are largely manual and craft-based and not readily automated. The limited modelling/monitoring of manufacturing processes necessitates large safety margins, long new-product introduction processes, and a lack of in-field performance and fault propagation understanding.

The lack of automation-ready manufacturing processes also limits component standardisation, digital quality assurance integration, and the production efficiencies required to compete with more mature renewable energy sectors. Without a shift toward automated, digitally integrated manufacturing, assembly and installation systems, the ORE sector risks remaining locked in low-volume, high-cost production pathways that constrain industrial growth and supply chain participation.

AT A GLANCE

Sector Focus

Tidal | Wave | Offshore Wind | Beyond ORE

Innovation Type

- Cross-Cutting
- Accelerative
- Disruptive

Linked Challenge

A2

Cost Reduction

£

Research Grand Challenge Theme

Automation to improve productivity in manufacture, installation and Operations and Maintenance

The Research Challenge

Development and demonstration of advanced manufacturing, assembly and installation approaches for ORE devices and subsystems is needed, including for blades, structures, component housings and floating systems. Integration of robotic fabrication and assembly is needed for complex subsystems, including Power Take Offs (PTOs), and digital manufacturing systems integrating digital twins and real-time production monitoring together with modular manufacturing designs suited for automation-ready serial production, will enable advanced manufacturing processes for ORE and support digitalisation of the entire ORE system lifetime. Improvements are sought that can demonstrate a credible pathway to automated or scalable manufacturing, assembly and installation.

Research is needed to embed monitoring in manufacturing processes. For example, digital modelling and monitoring of composite manufacturing processes need to be advanced to enable through life load prediction of as-built modular components. Steel welds are already analysed to determine residual stresses at fabrication stage, and comparable techniques are needed for other materials and components to understand performance degradation and the early life catastrophic failures seen in recent deployments.

Outcomes (Technical)

- Automation-ready manufacturing systems will significantly reduce production costs, improve component quality and enable reliable high-volume manufacturing of ORE devices and subsystems.
- Digitalised assembly and installation approaches for fixed and deep water systems will support better through-life prediction when allied with structural health and condition monitoring.
- Better understanding of materials and manufacturing processes will reduce LCoE through increased production yield and reduced process time, faster new product introduction, reduced rework, and improved product performance.
- Better understanding of through life performance of as-built modular components.

Impacts (UK plc)

- Facilitate automation of large scale support structures, including for deeper water.
- Automation in assembly and installation will enable faster deployment and improved safety.
- More productive blade manufacturing for wind, addressing the 20% productivity increase targeted in the Industrial Growth Plan [7].
- Establishing commercially efficient manufacturing processes for tidal stream and wave energy systems.
- Facilitate both energy and supply chain security.
- Unlock high value manufacturing jobs accounting for 50% to total project values.

A.2: Develop and demonstrate materials and processes for sustainable manufacture to enable circular use of ORE components

Context

At present, turbine blades are predominantly made from composite materials comprising thermoset resins with glass and carbon fibre reinforcement. They are one of the main components of a wind turbine, which is currently difficult to recycle and contribute around 10-15% of the overall lifecycle emissions. At end-of-life, current composite blades are typically mechanically recycled into lower grade products or fillers, co-processed into cement clinker (glass fibre only), or incinerated or disposed of in landfill. These options are not expected to be acceptable in the future, as we move to a more circular economy, so innovations to facilitate full recyclability are required. Recyclable resin systems are beginning to be deployed in the wind sector, but they are not integrated into circular supply chains.

AT A GLANCE

Sector Focus

Tidal, Wave, Offshore Wind, Beyond ORE

Cost Reduction

Innovation Type	Linked Challenges
Cross-Cutting	A1
Accelerative	A4
Disruptive	

Research Grand Challenge Theme

Next generation ORE systems to achieve sustainable lifecycles with reduced reliance on critical raw materials

The Research Challenge

Novel methods are required for extracting maximum value from legacy materials through understanding their residual properties and market potential. While recyclable resin materials are becoming available for new wind turbine blades the performance of the recovered materials is not fully understood and research is needed to identify opportunities for reuse of these materials in ORE and other applications. Other components, such as structural materials and rare earth magnets, require new processing methods to enable circular use. Incremental improvement to current materials and processes are not within the scope.

Outcomes (Technical)

- New processes for material recovery and the identification of new applications of recovered materials in ORE and other sectors.

Impacts (UK plc)

- New UK business opportunities in the recovery of high value materials, particularly rare earth materials, as the scale of decommissioning accelerates.
- Enable circularity to be embedded in design processes at early stage, particularly for tidal and wave technologies prior to scale-up.
- Improve public perception of the recyclability of wind turbine blades.

Siemens Gamesa, Transformer Core Processes

A.3: Next generation PTO systems for ORE applications to improve performance and reduce cost

Context

Power take-off systems (PTOs) encompass the full electro-mechanical drivetrain of an ORE device and represent a significant proportion of project capital expenditure and technical risk. The ORE PTO market is mature and highly concentrated, particularly in offshore wind, where design conventions have largely converged on permanent magnet synchronous generator (PMSG) architectures. Deployed in direct-drive or geared configurations, these PTOs are typically supplied either in-house by major continental OEMs or by a limited number of established European electrical machine manufacturers. As a result, the high-value electro-mechanical segment of the ORE value chain is predominantly captured outside the UK. Incremental optimisation of incumbent drivetrain platforms is unlikely to materially shift this structure. Next generation PTO concepts would have benefits for offshore wind, tidal stream and wave energy, where it could lead to novel concepts, and also move towards convergence of ORE solutions.

The Research Challenge

Development and demonstration of novel PTO architectures, such as superconducting machines, and those with reduced use of critical materials offer the potential for step-change improvements in performance over incumbent platforms, progress towards standardisation, and establish credible entry points for UK-based suppliers. Rather than incremental optimisation of conventional drivetrains or marginal efficiency improvements, disruptive innovation is needed.

AT A GLANCE

Sector Focus

Tidal | Wave | Offshore Wind

Innovation Type

- Cross-Cutting
- Accelerative
- Disruptive

Cost Reduction £

Research Grand Challenge Theme

Standardisation of ORE systems and integration into modernised energy grids

Outcomes (Technical)

- Development of paradigm-shifting PTO systems capable of unlocking step changes in performance, reliability and cost reduction across ORE technologies.
- Significant improvement in performance, reliability and cost reduction across ORE.

Impacts (UK plc)

- Establishing a UK-based PTO design and supply chain offers potential for significant UK investment.
- Bringing a new PTO to market by 2040 would enable deployment on the 50+ GW new-build and 10's GW offshore wind site re-powering projects expected from 2040+.
- Potential for inclusion of new PTO technologies in first commercial arrays for tidal and wave as the sectors scale up from 2035.

What We Are Working On

Tidal Turbine Benchmarking

Leadership of large-scale experimental campaign and co-ordination of community benchmarking is providing increased confidence in model predictions of tidal turbine loading [8, 9]. This is enabling reduction of conservatism in the design of tidal turbines, particularly for fatigue loading, benefiting overall system cost.

A.4: Develop decommissioning and repowering capabilities to sustain generation from existing ORE sites and improve sectoral circularity and sustainability

Context

The UK and Europe will be at the forefront of the wave of decommissioning and repowering of ORE sites in the coming decades. The recent growth in ORE capacity will be followed, one design life later, by the same acceleration of decommissioning requirements, as well as repowering of sites to maintain the generation capacity. Current methods for safe and sustainable end-of-life actions for offshore wind – whether decommissioning, repowering or life extension – are in their infancy. Also, end-of-life decisions depend on interrelated technical, socioeconomic and environmental considerations. The value of equipment, materials, economic activity and the ecosystems associated with a life-expired wind farm require preservation, as far as is possible, while the generation capacity needs replacement.

AT A GLANCE

Sector Focus

Tidal | Wave | Offshore Wind

Innovation Type	Linked Challenges
Cross-Cutting	A2
Accelerative	D1
Disruptive	

Cost Reduction £

Research Grand Challenge Theme

Next generation ORE systems to achieve sustainable lifecycles with reduced reliance on critical raw materials

The Research Challenge

Reuse and recycling capabilities of materials and sub-structures in ORE systems needs to be better understood as well as techniques to assess the condition (and the remaining useful life or the current characteristics) of materials, components, seabed and ecosystems around late-life ORE systems. Solutions are needed to unlock technological options for repowering existing turbines or wind farm sites, optimising the sustainability and socio-economic outcomes.

Appropriate policy tools and regulations are needed to grow and direct the sectoral capabilities to implement end-of-life and repowering solutions in time and at scale for the UK's forthcoming needs.

Outcomes (Technical)

- Developed UK capabilities to sustain generation from existing wind farm sites.
- Improved end-of-life outcomes based on socioeconomic and environmental metrics.

Impacts (UK plc)

- Expected to affect around 3.5 GW existing fixed offshore wind reaching end of life by 2035 and 10 GW by 2040. One year life extension or repowering of 10 GW capacity could represent 10% of UK electricity demand, thus massively reducing consumer cost compared to 10 GW new build for the same output.
- By ensuring circularity of the tens of GW of future offshore wind now in development (to 2035) and further capacity planned beyond, including tidal stream and wave energy, reputational risk for the sector will be mitigated.
- There are opportunities for new businesses building on the UK's early experience in dealing with the end of life of large-scale ORE assets.

Supergen ORE Hub Masterclass at the National Decommissioning Centre

RESEARCH CHALLENGES

Guiding UK research and innovation towards high-impact challenges

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B.1 Develop innovative seabed connection systems to enable access to a wider range of ORE resources

Context

ORE system performance relies on a structural or mooring system to provide a reaction to the operating loads, other metocean loading and system weight. Stability and station-keeping must be maintained within prescribed limits during installation, operation and extreme conditions. The seabed connection system – whether a foundation or a mooring and anchoring system – must efficiently satisfy these limits, while being installable in wide weather windows at low risk, ideally with a flexible supply chain including local content.

Current designs for foundations, mooring systems and anchors for deeper water and more energetic sites do not fully account for complex platform motions, coupled load paths, and fatigue, leading to uncertainty and high conservatism in design, affecting project viability and LCoE. Improved designs will make more ORE sites technically accessible and reduce cost and risk for accessible sites that are not economically viable.

Emergent innovations in seabed connection system are partly driven by array configurations or upscaled platforms. These include shared moorings and anchors, and new mooring and anchor types. Innovative mooring sub-systems, such as non-linear components, can mitigate extreme loading, easing design requirements. Innovative anchoring systems are urgently needed in geologically-complex regions, notably the Celtic and Irish Seas, and particularly where seabed rock is present, making capacity uncertain and installation risk high.

AT A GLANCE

Sector Focus

Tidal | Wave | Offshore Wind

Innovation Type	Linked Challenges
Cross-Cutting	A1
Accelerative	B4
Disruptive	

Cost Reduction £

Research Grand Challenge Theme

Standardisation of ORE systems and integration into modernised energy grids

The Research Challenge

Evolved ORE structural systems, alongside vessels that can deploy them, are required for deeper water beyond current fixed wind and tidal stream designs, alongside commoditised mooring and anchor systems for floating ORE systems (wind, wave, tidal stream).

New designs that reduce through-life loading action responses will cascade benefits through the design process by minimising structural and geotechnical loading. This will include the use of controllable elements in the mooring system to change the overall mass distribution or damping, and will be driven by optimisation for manufacturability and installation (see A1). Potential design innovations include the adoption of innovative structural configurations, mooring lines, anchor types and load-reducing concepts.

Foundation and anchoring system innovations are required to meet harsh loading demands with acceptable installation methods – in terms of failure risk, weather operability and environmental impact (e.g. noise). Pathways to achieve this include harnessing novel installation processes, such as 'silent' techniques or robotic micro-piling. Innovations suited to regions with complex geology are particularly urgent.

Outcomes (Technical)

- Extended fatigue life of mooring cables and connectors increasing operating life.
- Reduction of overall system weight and cost.
- Design convergence for floating systems enabling commoditisation.
- New seabed connection systems for highly tidal zones and/or areas of seabed rock.
- Innovative anchor installation processes e.g. low noise or 'silent' technologies, and remote-controlled robotic systems.

Impacts (UK plc)

- Key enabler for deeper-water wind which represents over 50 GW in UK sites.
- Potential for major UK export market as identified by the Industrial Growth Plan [7].
- New solutions can be incorporated into UK supply chain and support future tidal and wave sectors scale up.
- Access to new ORE resources in highly energetic tidal stream zones and/or areas of seabed rock enabled.

STEM Outreach Activity with Young People in Devon

B.2 Prediction of operating and extreme conditions to improve design of systems in arrays

Context

ORE systems deployed in an array experience different operating conditions from those deployed in isolation due to the influence of other devices on flow speeds, turbulence and waves. A wide combination of conditions occurs and existing design methodologies for the loading actions are simplified. For example, design conditions for waked turbines typically account for elevated turbulence but can neglect wake velocity reduction. Blades, structures and foundations are dependent on prediction of ultimate-and fatigue-load and so even small percentage reductions in the severity of these load cases through reduced uncertainty or improved physics can significantly impact project cost.

AT A GLANCE

Sector Focus

Tidal | Wave | Offshore Wind

Innovation Type	Linked Challenges
Cross-Cutting	B3
Accelerative	D5
Disruptive	

Cost Reduction £

Research Grand Challenge Theme

Modelling & Predictive capabilities that accelerate innovations to reduce reliance on large scale real-world operational experience

The Research Challenge

Development and validation of modelling tools for predicting loading actions and system responses. This includes the perturbation of turbulent flow due to turbine/device operation, and the development and validation of models for predicting interaction of waves with turbulent flow to establish wave development due to wakes (wind) and wave modification by wakes (tidal). Development of AI/ML methods that can be robustly integrated to accelerate analysis. This will require better use of operational, experimental and manufacturing data to achieve efficient use of data and reliability of predictions across the design space.

Real-world validation data using measurements of atmospheric flow over the vertical extent of modern wind rotors, or marine boundary layer height for tidal turbines, and full-scale measurements of turbulent wakes in representative operating conditions are needed. Wave modification as a result of array interaction between floating bodies also needs to be fully captured. This will require concurrent multi-point or multi- physics measurements in proximity to operating ORE systems as well as innovations in instrumentation to provide datasets that can be employed for model development and validation.

Methodologies to efficiently identify design loading actions from the wide range and combination of conditions that can occur within large arrays, and to predict the change of occurrence of metocean conditions through the required operating life of ORE systems, including under a changing climate.

Outcomes (Technical)

- Improved assessment of loading actions and system responses to enable design closer to material limits.
- Maximise operating life of existing ORE farms, minimise costs of next generation ORE farms.
- Demonstrate enhanced performance through array benefits for wave energy systems.

Impacts (UK plc)

- Extend service life of >16 GW of wind turbines currently in operation.
- Reduced costs through more optimised designs.
- Minimise capital cost, and LCOE of 43-60 GW offshore wind farms now in development.
- Minimise capital cost of >130 MW tidal projects now in development and all future tidal stream projects.
- Improve confidence in wave energy potential.

What We Are Working On

Accounting for Inter-Farm Effects

Improved understanding of wake effects between wind farms in close proximity is being unlocked through our collaborative research [10, 11]. These advances developing our understanding of modelling accuracy and capabilities inform wind farm planning and streamline project development.

B.3: Develop validated physics-based coupled models to improve system design

Context

Current approaches for the design of complex floating ORE systems typically rely on segregated modelling frameworks that treat individual system elements (e.g. turbine, hydrodynamics, structure, soil) independently. These approaches are unable to accurately capture the coupled whole-system response under specific load cases, (e.g. extreme sea states), which can lead to conservative design in some cases and unexpected failure modes in others. Because global and local models are not fully aligned, and assumptions often limit accuracy, the industry still faces high uncertainty in predicting fatigue and failure modes. Current practice relies on a mix of global simulation tools and detailed local finite element analysis (FEA). Results are sensitive to input parameters, often not sufficiently validated with test data, and can produce unrealistic behaviour if used outside their assumptions.

Although high-fidelity coupled modelling approaches exist, they remain computationally prohibitive for iterative whole-system design and optimisation of floating systems. AI/ML is beginning to emerge within ORE, reducing computational costs and increasingly applied to optimisation problems. However, uptake in ORE is limited by poor data availability, fragmented applications and lack of trust. With the right approach, AI/ML will enable faster, more integrated and more efficient design.

AT A GLANCE

Sector Focus

Tidal | Wave | Offshore Wind

Innovation Type	Linked Challenges
Cross-Cutting	B2
Accelerative	D5
Disruptive	

Cost Reduction £

Research Grand Challenge Theme

Modelling & Predictive capabilities that accelerate innovations to reduce reliance on large scale real-world operational experience

The Research Challenge

New modelling tools are required that can represent the relevant coupled physics governing floating ORE systems, dynamic power cables and seabed connections at device scale, while remaining computationally efficient for iterative whole-system design including critical design load cases. Determination of the appropriate level of modelling fidelity required to accurately predict coupled whole-system response across different conditions and design applications, and establishing clear limits of validity. There is also a need to develop robust approaches for uncertainty quantification, validation and interpretability, providing confidence in both physics-based and AI/ML-enabled engineering tools and supporting their adoption in industrial decision-making.

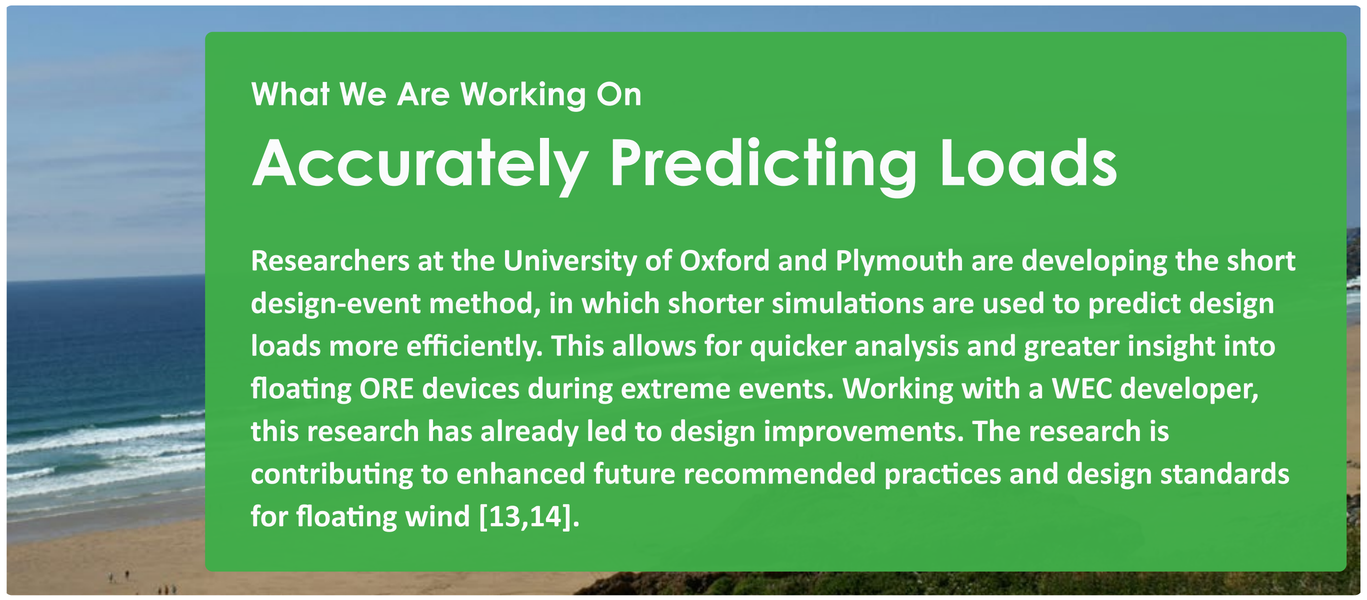
Validation against appropriate experimental and physical test data across different operating regimes using multi-disciplinary approaches that combine environmental, structural, control, and ecological factors into coherent, realistic testing, that better capture system complexity to reduce risk and cost is needed. This research should deliver modelling capabilities that are sufficiently robust, well-documented, and open-source (where appropriate) to support adoption in both academic research and industrial design practice.

Outcomes (Technical)

- Integrated and coupled modelling that is computationally efficient and reduces conservatism in design.
- Optimised ORE designs that improve energy yield, reliability, and survivability while reducing costs through lower material requirements and extended operational lifetimes.
- Accelerate design and certification cycles through improved modelling capabilities and more efficient exploration of design spaces.
- Increased confidence through validation, uncertainty quantification and interpretability.

Outcomes (Technical)

- Lower cost of ORE through more efficient design and development processes. For example, a 10% reduction in the cost of floating wind substructures could save approximately £500m for a typical 3 GW floating wind farm [12].
- Accelerate innovation by reducing cost of field trials and de-risking technology demonstration and deployment.



What We Are Working On

Accurately Predicting Loads

Researchers at the University of Oxford and Plymouth are developing the short design-event method, in which shorter simulations are used to predict design loads more efficiently. This allows for quicker analysis and greater insight into floating ORE devices during extreme events. Working with a WEC developer, this research has already led to design improvements. The research is contributing to enhanced future recommended practices and design standards for floating wind [13,14].

B.4 Integrate foundation models and site characterisation to unlock design innovations and shorten development timelines

Context

ORE projects involve complex loading conditions, including wave, current, wind and seismic actions leading to operational, accidental and extreme load cases. Storms apply hours of cyclic loading, and lifetime loading can accumulate to >100 million cycles. ORE foundation or anchoring systems must accommodate the aggregated effect of all these loads through new design procedures.

ORE farms span hundreds of square kilometres of seabed, across which the soil strata vary significantly. This reflects layered ground conditions ranging from clays, silts and sands, to hard bedrock such as chalk or mudstones. Identifying the spatial distribution of these seabed materials and their relevant design parameters is critical for reliable and efficient foundation or anchor design. As ORE structures become larger, design for cyclic loading becomes more critical compared to design for a single extreme event.

Wind farm site characterisation typically involves multiple years of surveys and data synthesis before project Final Investment Decision (FID). Designs mature iteratively as the site characterisation is refined to address emerging criticalities and design opportunities. This places site characterisation on the project critical path, consuming significant development expenditure, and potentially controlling project viability.

AT A GLANCE

Sector Focus

Tidal | Wave | Offshore Wind

Innovation Type	Linked Challenges
Cross-Cutting	B1
Accelerative	
Disruptive	

Cost Reduction £

Research Grand Challenge Theme

Modelling & Predictive capabilities that accelerate innovations to reduce reliance on large scale real-world operational experience

The Research Challenge

Substantial recent research progress has improved assessment of the ultimate capacity of pile foundations (e.g. via the PISA project), which now forms routine practice. The next two challenges are (i) to assess the impact of storm loading and life-time loading, with new robust procedures for the cyclic loading of geomaterials and (ii) to refine or reinvent site characterisation practices, to better suit design input requirements, harnessing emergent survey platforms and geo-technologies.

Addressing challenging ground conditions is critical, requiring improved soil constitutive models implemented within computational analyses to robustly simulate cyclic load responses. Modern foundation/anchor design across vast wind farm sites requires more strategic site characterisation approaches that better synthesise in-situ measurements – both geotechnical and geophysical – and laboratory-based measurements through a quantitative ground model. AI/ML can enhance layer mapping and engineering parameter assessment via geophysical-geotechnical data fusion. In parallel, improved in-situ and laboratory tests can target inputs for new models of soil-structure or rock-structure interaction. These technologies reduce reliance on traditional costly and time-consuming sampling and testing campaigns.

Outcomes (Technical)

- Optimisation of cyclic loading design to create site-specific models and assessments.
- Improved site investigation strategies and tools, optimised for specific ORE foundations/anchors and their design approaches, with better integration into the design work flow.
- Better interpretation and integration of site investigation techniques, including the use of AI/ML to estimate site conditions between measured data.

Impacts (UK plc)

- Significant cost savings through reduced weight of steel used for the foundations and anchors. Across a wind farm of 100 to 200 turbines these material savings could represent £100m, or more [15].
- Survey timescale reductions reducing development expenditure and enabling earlier FID.
- Construction cost benefits from reduced installation risk and better assessment of design risk.
- Access to ORE sites where new technology and design techniques are needed to enable a feasible and economic design.

What We Are Working On

Targeting High-Cost Components

Recent research has supported new design guidance for pile foundations in chalk materials, enabling optimisation of pile lengths, reduced installation risk and better quantification of overall design risk. This could result in significant cost savings across projects, particularly in offshore wind, where foundations can account for up to 25% of the installed capital cost. [16, 17]

RESEARCH CHALLENGES

Guiding UK research and innovation towards high-impact challenges

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C.1: Novel materials and designs for offshore cables and electrical components to improve performance, reliability and circularity

Context

Offshore cables are reaching their design limits; higher voltage, increased dynamic requirements and longer lifetime requirements need to be achieved in order to meet high reliability expectations. Current cable materials and designs face significant challenges in achieving the long-term reliability required for future ORE deployments and in circularity. Failures remain costly, hard to repair, and increasingly difficult to insure against. Most subsea cables rely on conventional polymers, metals, and armouring concepts that were not originally designed for ORE demands, regarding loading cycles, thermal limits, or installation challenges.

Furthermore, offshore wind projects are moving to higher voltages (e.g., 132 kV) to reduce electrical losses. That brings rising electric field stress, partial discharge risk, thermal bottlenecks, stiffer designs with tighter bend radii, and connector/termination challenges. For floating assets, motion induced fatigue, water treeing risks, and HV joint reliability are challenging, and there is a need for purpose-built 132 kV dynamic cables.

AT A GLANCE

Sector Focus

Tidal | Wave | Offshore Wind | Beyond ORE

Innovation Type

- Cross-Cutting
- Accelerative
- Disruptive

Cost Reduction £

Research Grand Challenge Theme

Next generation ORE systems to achieve sustainable lifecycles with reduced reliance on critical raw materials

The Research Challenge

A step-change in materials and design concepts is needed through development of novel materials, smart (remotely monitored) structures, and design approaches that enhance cable performance and reliability. This could include advanced polymers, bio-based or recyclable materials, new conductor concepts, smart sensing layers, or modular designs. Insight into material behaviour, improved design configurations and early cable prototypes will enable new developments that improve cable performance and reliability and allow better installation. Embedded sensing or modular components could transform inspection and repair strategies.

Multi-physics modelling frameworks are needed for design, combining electrical, thermal, mechanical and electromagnetic effects for improved modelling of component degradation and failure mechanisms and for advanced power electronics and HVDC transmission systems. The development of 132 kV reliable cable systems (array, and dynamic) is needed, with improved dielectrics, field grading, and moisture barriers to limit PD and water-treeing, and ensure resilience to motion-induced fatigue.

Outcomes (Technical)

- Improve confidence in global simulations, reducing modelling uncertainty.
- Design rules and test protocols for 132 kV static and dynamic cables.
- Improved cable performance and reduced electrical losses with validated cable reliability.
- Cable and component monitoring sensors and systems to inform reliability models and maintenance regimes.

Impacts (UK plc)

- Cables have the potential to become one of the key UK-manufactured components in future ORE deployments, providing significant opportunities for the UK in domestic and export markets [18].
- Reduced cable failure risks and increased investor confidence in ORE, where currently 80% of insurance claims in ORE are attributed to cable failures [19].
- Reduced installation, operational and downtime costs, estimated at many millions per cable failure [20].
- Bankable 132 kV dynamic cable systems enabling larger floating wind farms and lower lifecycle cost.

What We Are Working On

Advancing Subsea Cable Standards

Collaborative research with industry partners has transformed the design of subsea power cables for offshore renewables. The findings have been incorporated into the British Standard BS10009, enabling lighter, more cost efficient cable designs that reduce material use, installation costs and environmental impact. The guidance has already supported over 25 GW of renewable energy projects worldwide and over 4,000 km of subsea cables [21]

C.2: Develop whole system approaches for energy systems integration and security to improve ORE utilisation and reduce infrastructure costs

Context

Current grid integration approaches largely treat generation, transmission and storage as separate system elements. ORE farms are typically connected using point-to-point transmission systems and planned using deterministic assumptions about generation and demand. As the UK moves toward tens of gigawatts of offshore wind, plus the addition of tidal and wave generation, these approaches are increasingly inadequate. High penetrations of converter-dominated renewable generation introduce challenges including reduced system inertia, complex control interactions, network congestion and increasing curtailment. UK-wide curtailment and balancing costs reached approximately £1.46bn in 2025, up from £1.23bn in 2024, and are projected to rise to as much as £8bn per year by 2030 without significant grid and system integration reform [22, 23]. Furthermore, the integration of predictable cyclic tidal power combined with battery storage could reduce the investment otherwise needed in baseline nuclear power.

Ensuring ORE infrastructure remains secure, resilient and operational under environmental, technical and malicious threats is a critical challenge for the sector. As ORE scales up, increased digitalisation, remote operation and system connectivity introduce new vulnerabilities, with offshore assets being geographically distributed and difficult to access, increasing exposure to cyber-attacks, physical disruption and hostile actions.

AT A GLANCE

Sector Focus

Tidal | Wave | Offshore Wind | Beyond ORE

Innovation Type

- Cross-Cutting
- Accelerative
- Disruptive

Cost Reduction £

Research Grand Challenge Theme

Standardisation of ORE systems and integration into modernised energy grids

The Research Challenge

There is a need for energy system modelling tools that treat generation, transmission and storage as an integrated system. This will involve the development of tools and methods that enable integrated design and optimisation of ORE farms with electricity networks. Integrated modelling of generation, transmission and energy storage systems, to manage variability and reduce curtailment, will enable optimisation of the interconnected designs for farm, cluster and basin-scale to be explored and hence reduce overall system costs. It will also allow development of hybrid AC/DC grid architectures and offshore energy hubs, as well as the quantification of system-level benefits of storage and coordinated system operation for project design and wider strategic decision-making. At the system level, tools are needed to model the integration of ORE generation clusters with electricity network operation and planning, and quantify the system-level benefits of coordinated offshore renewable deployment.

Precedent from the wind sector underscores the stakes: a 2022 ransomware attack on Deutsche Windtechnik disrupted remote monitoring of around 2,000 turbines in Germany, while a separate cyberattack on Vestas compromised company data and disrupted parts of its internal IT infrastructure [24]. Advances are therefore needed in cyber-physical modelling of offshore energy infrastructure and communication networks to assess the vulnerability and resilience of interconnected energy system assets and design secure architectures with detection and mitigation strategies for cyber-attacks on operational technology systems embedded within them. Protection strategies and regulatory assurance frameworks are also needed to safeguard ORE infrastructure against physical disruption, sabotage and hostile actions.

Outcomes (Technical)

- Enable improved system stability and operational flexibility with high penetrations of ORE generation.
- Reduce curtailment and improve utilisation of ORE assets.
- Reduced vulnerability to cyber threats, physical disruption and hostile actions.

Impacts (UK plc)

- Enables planning of UK energy system infrastructure investments to deliver 2050 targets.
- Reduce infrastructure costs through improved system design and operation.
- Protection of ORE as critical national infrastructure.
- Ensures cybersecure ORE infrastructure design and operation.

What We Are Working On

Supporting the Grid's Transition to Renewables

Collaborative research with the UK's National Energy System Operator (NESO) has developed a real-time electromagnetic transient simulation framework for assessing the stability of power systems with large-scale offshore wind and HVDC connections. Integrated into Great Britain's grid modelling framework, RealSim improves the accuracy of stability analysis, supports operational decision-making, and positions NESO to lead in the transition to a renewable-dominated, low-inertia power system [25].

RESEARCH CHALLENGES

Guiding UK research and innovation towards high-impact challenges

In consultation with stakeholders across the sector, these research challenges have been identified as having the greatest potential for impact. They sit within four industry priority areas and are disruptive, accelerative, and reach across offshore wind, tidal stream and wave energy.

Each Research Challenge below links to a description of the challenge, the underpinning research required, and how it can generate impact for technology development and for the UK.

A. Next Generation Technologies/Subsystems

A1 Advance manufacturing, assembly and installation processes to enable ORE scale-up
Page 29

A2 Develop and demonstrate materials and processes for sustainable manufacture, to enable circular use of ORE components.
Page 31

A3 Next generation PTO systems for ORE applications to improve performance and reduce cost.
Page 33

A4 Develop decommissioning and repowering capabilities to sustain generation from existing ORE sites and improve sectoral circularity and sustainability.
Page 35

B. Industrialised Foundations and Substructures

B1 Develop innovative seabed connection systems to enable access to a wider range of ORE resources.
Page 39

B2 Prediction of operating and extreme conditions to improve design of systems in arrays.
Page 41

B3 Develop validated physics-based coupled models to improve system design.
Page 43

B4 Integrate foundation models and site characterisation to unlock design innovations and shorten development timelines.
Page 45

C. Future Electrical Systems & Cables

C1 Novel materials and designs for offshore cables and electrical components to improve performance, reliability and circularity.
Page 49

C2 Develop whole system approaches for energy systems integration and security to improve ORE utilisation and reduce infrastructure costs.
Page 51

D. Next Generation Processes and Services

D1 Improve condition monitoring/ instrumentation systems to enable predictive maintenance planning and end of life decisions.
Page 55

D2 Integrate observation, modelling and forecasting of engineered ORE systems, metocean conditions and ecosystems to optimise design, operation and siting.
Page 57

D3 Develop novel nature-based solutions to maximise environmental benefits of ORE.
Page 59

D4 Develop autonomous systems and real-time modelling tools to optimise safety and efficiency of maritime logistics, offshore asset and project lifecycle activities.
Page 61

D5 Advance and validate ORE farm performance and yield prediction to ensure confidence in revenue predictions over operating life in an evolving climate.
Page 63

D.1: Improve condition monitoring/instrumentation systems to enable predictive maintenance planning and end of life decisions

Context

The current lack of through-life data on individual devices and systems limits the ability to plan maintenance, determine remaining useful life and make life extension/ end of life decisions. Structural health monitoring and condition monitoring of some individual components is well established, but integrated device (Turbine/ WEC) level monitoring of large structures is less developed. Robust reliability and degradation models of some components (particularly composites) linked to as-built characteristics are lacking, making maintenance decisions difficult and limiting the ability to make repair, reuse and end of life choices. This means that cost effective array scale deployment, including population-based analysis, remains challenging.

AT A GLANCE

Sector Focus

Tidal, Wave, Offshore Wind

Innovation Type	Linked Challenges
Cross-Cutting	A4
Accelerative	D4
Disruptive	

Cost Reduction £

Research Grand Challenge Theme

Next generation ORE systems to achieve sustainable lifecycles with reduced reliance on critical raw materials

The Research Challenge

Deployable existing and novel sensors will be needed for monitoring through life, from manufacture, assembly, transport/installation, operation and repair, and integration into reliability and degradation models for device and array scale monitoring to support operations and maintenance, life extension and end of life decisions, including component and material re-use options.

Novel sensor types and/or integration methods are required to enable monitoring key components, such as turbine blades and moorings, throughout their lifetime in an integrated and cost effective manner. Integration of information from heterogenous sensor types and components is needed to understand complex loading conditions and associated damage and fatigue. In addition, population based modelling and behaviour prediction tools are required to support maintenance and end of life decision making.

Outcomes (Technical)

- Better informed operations and maintenance decisions to optimise performance.
- Better informed end of life or life extension decisions for components, devices and farms.

Impacts (UK plc)

- Reduced operating cost and optimised lifetime energy yield.
- Extend service life of >16 GW of offshore wind turbines currently in operation.
- 1 year life extension of 10 GW capacity could represent 10% of UK electricity demand, thus massively reducing consumer cost compared to 10 GW new build for the same output.

What We Are Working On

Influencing Strategic Decision Makers

A series of policy guidance reports distil complex ORE challenges and opportunities into actionable insights. Produced by the Policy and Innovation Group, the series provides evidence-based guidance to support decision-making and help ensure the sector plays its important role in achieving Net Zero targets [26].

D.2: Integrate observation, modelling and forecasting of engineered ORE systems, metocean conditions and ecosystems to optimise design, operation and siting

Context

Co-design for ORE farms that combines observation, modelling and analysis of resource, environmental loads, seabed conditions and ecosystem interactions for optimised design and operation will result in more sustainable and resilient engineering solutions. Observations are needed at regional levels simultaneously across multiple species to understand the full cumulative ecosystem effects and differences of effects in different habitats. Currently, observations are taken one species group at a time with no opportunity to provide information on linkages between them that provide mechanistic reasons for changes in ecosystem functioning due to ORE (e.g. seabirds and their main prey items, pelagic fish, are not measured at the same time or spatial scales). There is a need to include ecological monitoring into observations, modelling and forecasting, combined with physical environmental measurements so that information on ecological linkages, such as between measurable animal behaviour and physical forcing can be determined [27].

The Research Challenge

Fully integrated use of smart, autonomous instruments used across contrasting habitat types within a large region can detect and identify bio-physical water column characteristics, species groups and distinguish behaviours. Measurement instruments, such as ADCPs can be set up for dual engineering and ecological use. There has to be true step-change in the integration in monitoring efforts to provide simultaneous data on bio-physical variables as well as multiple species across the food chain (different trophic levels from low: plankton to high: top predators such as seabirds, marine mammals), rather than taking single species approaches. This will enable advances in environmental impact assessment and nature-based design for ORE systems and farms.

AT A GLANCE

Sector Focus

Tidal · Wave · Offshore Wind

Innovation Type	Linked Challenges
Cross-Cutting	D3
Accelerative	D4
Disruptive	

Cost Reduction £

Research Grand Challenge Theme

Multidisciplinary co-design of ORE systems for engineering and ecology

Outcomes (Technical)

- Improved levels of certainty in cumulative effects of ORE.
- Increased understanding of how ORE design, installation, and operations and maintenance affect ecosystems to determine optimal locations for arrays.
- Industry standards for ecological monitoring, pre- and post-consent that use autonomous smart technology with dual roles in monitoring for engineering purposes.
- Opportunities for novel bi-use instrument development and IP generation.
- Improved prediction of resource.

Impacts (UK plc)

- Reduced consenting costs and timelines for offshore wind, potentially saving ~£29m per 1 GW [28] offshore wind farm through a 40% reduction in consenting time [29].
- Ecological impact factored into the design of ORE farms resulting in more optimised designs and faster uptake.
- Evidence-based consenting frameworks for emerging tidal energy developments, helping to establish efficient regulatory processes as the sector scales.
- Positioning the UK as a global exporter of expertise, modelling capabilities, and decision-support tools for nature-based ORE design.

What We Are Working On

Wind Power Optimisation

Research-driven innovation is enabling greater efficiency from wind energy through AIOLUS, an AI-driven wind farm optimisation tool [30]. Using multi-agent reinforcement learning, AIOLUS coordinates turbine control across entire wind farms to maximise power generation under changing wind conditions, increasing annual energy production by up to 5% [31].

D.3: Develop novel nature-based solutions to maximise environmental benefits of ORE

Context

To be able to predict and provide proof of environmental benefit from Nature-Based solutions, such as changes to water column stratification and effects on whole marine food chains, requires improved monitoring approaches and the use of integrated smart, autonomous instruments. Most nature-based solutions currently focus on benthic improvements, such as providing new hard structure for positive marine growth and replacement of lost key habitat-building species such as the native oyster. A greater understanding of knock-on effects of changes to the pelagic environment up the food chain on fish, seabird and marine mammals is needed at a regional scale [27].

AT A GLANCE

Sector Focus

Tidal | Wave | Offshore Wind

Innovation Type

- Cross-Cutting
- Accelerative
- Disruptive

Linked Challenges

D2

Cost Reduction £

Research Grand Challenge Theme

Multidisciplinary co-design of ORE systems for engineering and ecology

The Research Challenge

There is a need to improve understanding of the spatial and seasonal changes to the levels of mixing (stratification) within the water column from both ORE structures and wind energy extraction. The level of planned ORE development will result in fundamental changes to marine ecosystems by altering the base of the marine food chain by modifying the timing, amount and species of plankton. These changes will have knock-on effects up through marine food chains, affecting fish production and spatial distributions, which in turn affects seabird and marine mammal populations. To enable the understanding of ecosystem level effects of changing in mixing will require new monitoring approaches that accurately predict ORE changes to ocean stratification and provide evidence on how ORE technologies and array siting can be designed for positive effects on marine ecosystems, such as efficiency of food chains and counteractions to climate change. Deeper understanding of links between physical changes in the water column and the functioning of marine ecosystems at regional level is needed, rather than at individual developments.

Outcomes (Technical)

- Validated integrated modelling frameworks linking ORE engineering, ocean-atmosphere dynamics and ecosystem responses using in-situ measurements from current ORE developments.
- Improved understanding of ORE impacts on marine ecosystems, enabling accurate prediction of the effectiveness and scalability of nature-based solutions by 2030.
- Deliver ORE devices and farm configurations to mitigate climate change impacts and sustain marine biodiversity.
- Accelerated decision-making tools and consenting processes for future ORE developments through improved predictive capability and evidence-based environmental assessments.

Impacts (UK plc)

- Early integration of nature-based solutions into offshore wind, tidal stream and wave energy device and farm design, reducing environmental risks and supporting sustainable deployment.
- Evidence to support the design of effective mitigation and compensation actions which will produce a reduction in consenting times by increasing certainty in environmental impacts.
- Evidence-based consenting frameworks for emerging tidal energy developments, helping to establish efficient regulatory processes as the sector scales.

What We Are Working On

Potential to Reduce Consent Time by 40%

Recent research is helping to transform environmental assessment for offshore renewable projects. By shifting from project-by-project environmental monitoring to the Regional Ecosystem Monitoring Programme (REMP) [27, 32], data will be collected much more efficiently whilst building a better picture of our marine ecosystems. An ORE Catapult report highlighted this approach could reduce consenting times by 40% [29].

D.4: Develop autonomous systems and real-time modelling tools to optimise safety and efficiency of maritime logistics, offshore asset and project lifecycle activities

Context

Maritime logistics take place in highly dynamic and uncertain offshore environments where safety critical decisions must be made rapidly. Autonomous systems — such as uncrewed surface vessels (USVs), autonomous underwater vehicles (AUVs), drones, and robotics — that function reliably in these environments could transform ORE installation, operations, maintenance and decommissioning. Accurately representing the offshore environment in which offshore wind, wave and tidal operate in real-time requires physics-based and machine-learning/ AI models that can assimilate live metocean data and forecasts, quantify uncertainty, and remain computationally efficient enough to support operational decisions such as vessel access, crew transfer, or installation windows without compromising safety margins. Robust perception, navigation, and localisation under uncertainty remain open research problems, particularly when combining multiple sensing modalities (sonar, vision, LiDAR, GNSS). Ensuring safe autonomy in close proximity to large structures, vessels, and personnel is especially critical during inspection, installation, and maintenance operations.

The Research Challenge

Development of real-time predictive digital twins/ virtual simulations, by integrating reduced-order and machine-learning models with heterogeneous operational data streams (e.g., sensors, vessel telemetry, metocean observations, and structural monitoring systems) will enable better prediction of vessel motions, station-keeping, contact dynamics, structural response, and equipment faults under uncertain offshore conditions. Together with advancing real-time optimisation and risk-based safety modelling, through probabilistic assessments and adaptive safety envelopes, this can enable dynamic and uncertainty-aware optimisation of maritime logistics operations. Coordinated human-autonomy operations requires the integration of autonomous air, surface, and subsea systems with robust communication, collaboration, and shared situational awareness. Use of these autonomous systems, alongside legacy assets, will require assurance frameworks to be established through the development of simulation-based verification, digital testing environments, transparent human-autonomy interaction, and regulatory compliance methodologies. It will also need trusted decision-support, training, and simulation environments that incorporate human factors, improve situational awareness, and support safe and effective offshore decision-making.

AT A GLANCE

Sector Focus

Tidal | Wave | Offshore Wind

Innovation Type	Linked Challenges
Cross-Cutting	D1
Accelerative	D2
Disruptive	

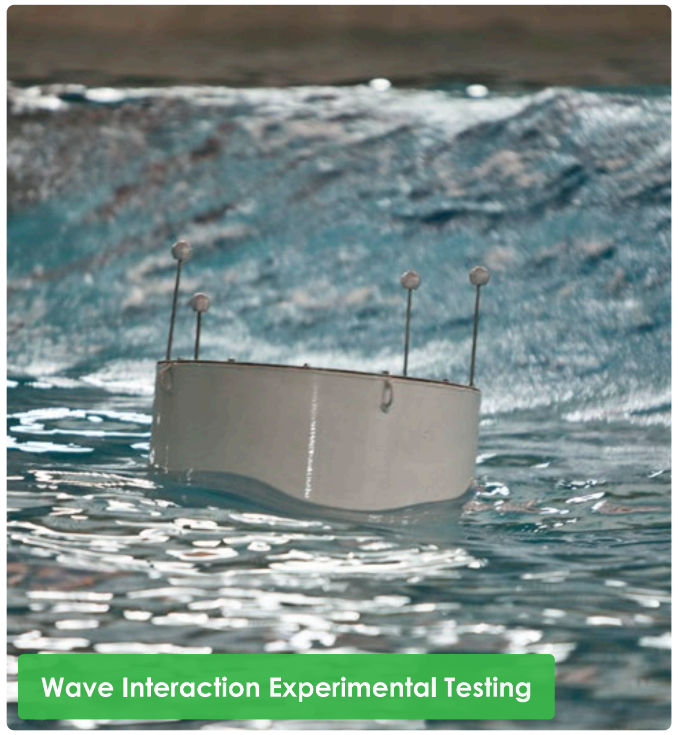
Cost Reduction £

Research Grand Challenge Theme

Automation to improve productivity in manufacture, installation and Operations and Maintenance

Outcomes (Technical)

- Increased trust in autonomous systems, improving safety, reducing operational risk, and lowering costs across the wind, wave and tidal asset and project lifecycle.
- Improved performance, reliability, and availability of ORE devices through the use of real-time operational data and predictive analytics, reducing downtime and extending asset lifetimes.
- Increased trust in operations and maintenance decision-making, including fault detection and condition assessment.



Wave Interaction Experimental Testing

Impacts (UK plc)

- Address the machine learning and autonomous vehicle challenges identified in the Industrial Growth Plan as critical to capturing the £404bn global market opportunity [7] for next-generation installation, operations and maintenance (2036–2050).
- Accelerate the commercialisation of wave and tidal energy by reducing installation, operations and maintenance, and decommissioning costs, which together account for around a fifth of project expenditure.
- Improve the safety of ORE operations, particularly installation and operations and maintenance activities, which account for a quarter of jobs over the project life [4].
- Increase offshore asset availability and energy production. For offshore wind assets operating at 90–95% availability, reducing component-related outages by 50% could deliver up to ~150 MWh [33] of additional annual generation per MW installed.

D.5 Advance and validate ORE farm performance and yield prediction to ensure confidence in revenue predictions over operating life in an evolving climate

Context

Robust and reliable yield prediction models are essential to provide confidence in long-term revenue projections, particularly in the context of an evolving climate. Current approaches typically combine site-specific metocean data with device performance characteristics and array interaction effects to estimate energy yield and associated uncertainties. However, these methods are constrained by limited availability of full-scale operational data for validation and are consequently subject to significant uncertainty, undermining investor and stakeholder confidence.

Multi-farm layout design, energy yield prediction and operational strategies are often developed independently and rely on simplified assumptions regarding interactions between devices, farms and the wider power system. As ORE deployment increases, particularly with large clusters of wind farms and emerging co-location with wave and tidal technologies, interactions between farms become increasingly significant. These include wake interactions (both within and between farms), electrical network constraints, shared infrastructure, environmental effects and operational coordination across large geographic areas.

Existing modelling tools generally lack the capability to integrate these multi-scale interactions across farm, cluster and basin scales, and do not fully capture the system-level benefits or constraints associated with coordinated operation and grid integration.

AT A GLANCE

Sector Focus

Tidal | Wave | Offshore Wind

Innovation Type	Linked Challenges
Cross-Cutting	B2
Accelerative	B3
Disruptive	

Cost Reduction ↓ £

Research Grand Challenge Theme

Modelling & Predictive capabilities that accelerate innovations to reduce reliance on large scale real-world operational experience

The Research Challenge

Development is needed of modelling and optimisation tools that support integrated planning and operation of multiple ORE systems within the same region. Farm- and basin-scale modelling tools for renewable energy generation and system interactions will enable layout optimisation considering wake interactions, electrical infrastructure and environmental constraints, as well as optimisation of installation and maintenance operations across multiple farms and technologies. Reliable predictions of resource and yield should also take account of climate change and the resulting metocean conditions.

Validated methodologies which account for physical processes beyond the operating ranges of existing farms are needed, such as interaction of tall wind turbines with the marine atmospheric boundary layer under different stability conditions, farm to farm interactions (wind and tidal), dynamic response and change of relative position within arrays accounting for mooring constraints in deep water.

Wave energy farms will comprise closely spaced devices whose hydrodynamic interactions could be exploited to enhance energy capture through constructive radiated wave patterns. Theoretical studies suggest energy yields could be up to 10x greater than the same wave energy converters in isolation. However, these predictions remain largely unvalidated, and the conditions required to achieve such gains are not yet well understood [34]. Further improvement to modelling predictions could be enabled by integration of measurement data with models to continuously enhance yield prediction accuracy, and accelerated through the use of AI/ML.

Outcomes (Technical)

- Increased confidence in energy yield and revenue predictions pre-consenting (wind and tidal).
- Increased accuracy of forecasting of supply from offshore renewables.
- Improved design and operation of ORE farms and clusters.
- Optimised use of offshore infrastructure and improved coordination between energy assets.

Impacts (UK plc)

- Increased confidence in wind farm revenue predictions, which would support sector investment for scale-up beyond 40 GW, and should enable reduction of project costs.
- Confidence in tidal stream farm revenue predictions, to enable private investment as arrays scale-up beyond the 140 MW now in development.
- Evidence base for the opportunity for longer-term energy supply from wave energy, 6 GW by 2050.
- Efficient deployment of large ORE clusters required for UK decarbonisation targets.

Section 4: Conclusion and Next Steps

The Value of Coordinated Research

There is little doubt that, in the coming decades, the offshore renewable energy (ORE) sector will play a critical role in delivering the UK's ambitions for both clean energy and economic growth. This growing importance is increasingly reflected across UK energy policymaking, where ORE is now viewed not simply as a source of clean electricity, but as a strategic national asset. As laid out in the statement accompanying the UK Government's latest Carbon Budget, "the only way to protect family and business finances is to drive for clean homegrown power that we control".

This is the role that a successful and commercially competitive UK ORE sector can play.

As identified in the *Supergen ORE Outlook 2040* report [6], our drive for clean homegrown power will only be achieved by upscaling and accelerating UK deployment through sustained innovation. For the UK, **this transformation is the industrial opportunity of the 21st century**, requiring substantial commitments to ensure that by 2040, the UK has: 7 times the ORE capacity; 4 times the rate of project development; and 6 times the workforce that it has today.

Ensuring that we secure this clean power – and the socioeconomic benefits associated with subsequent supply chains, jobs and exports – means maximising the homegrown aspect of the ORE sector. This can only be achieved through a concerted effort to increase domestic ORE content, both in the short- and long-term. Delivering this outcome in the face of enhanced competition from around the world is contingent on adopting a new approach to sector development – **embracing disruptive innovation across both ORE technologies and supply chains.**

The coordination of underpinning research is fundamental to this process. It provides the clarity and strategic direction required to:

1. identify the challenges that matter most;
2. focus effort on areas capable of delivering the greatest impact;
3. ensure that innovation activities remain aligned with the long-term needs of the sector.

It is this combination – the need to rapidly scale deployment while simultaneously sustaining a continual drive for disruptive innovation to increase competitiveness across the sector – that will best position the UK for long-term success.

The challenge, therefore, is how an ORE sector comprised of technologies at different stages of maturity can collectively contribute to this dual objective of deployment and innovation. While mature technologies are expected to deliver near-term capacity growth, emerging technologies require continued innovation support if they are to realise their longer-term potential.

As reflected in the *Clean Power 2030 Action Plan* [2], fixed offshore wind has now established itself as a mature and globally competitive industry, with a clearly defined role within the UK's energy system that includes more than tripling current installed capacity by 2030. However, for more innovative technologies such as deep-water offshore wind, tidal stream and wave energy, it is necessary to extend the time horizon beyond the immediate deployment ambitions of *Clean Power 2030* and towards the longer-term opportunities identified by the *ORE Outlook 2040* and the UK's 2050 Net Zero ambitions [35].

Viewed through this longer-term lens, the value of coordinated underpinning research becomes increasingly apparent. While offshore wind, tidal stream and wave energy each face distinct challenges, they also share many core technology subsystems, industrial requirements and innovation needs. This creates a significant opportunity for coordinated research activities to deliver benefits across the wider sector. It is within this context that the SRA has been developed. By identifying the underpinning research challenges that will shape future innovation, and by providing a framework through which these challenges can be coordinated and prioritised, the SRA seeks to strengthen the foundations upon which the future development of the UK ORE sector depends.

Supergen ORE Hub Annual Assembly Connecting Academia, Industry and Policy Stakeholders

Progress So Far

Clean Energy | UK Competitiveness

- UK greenhouse gas emissions have decreased by 54% from 1990 levels [1]
- Renewables generated 53.1% of the country's electricity in Q1 2026 [36].
- 2025: a record year for periods where electricity demand was 100% met by clean energy [37].
- The UK is a global technology leader in ORE
- Offshore wind powers around 15 million homes [38]

We should celebrate the huge strides made by the UK and ORE sector in taking climate action to reduce GHG emissions, grow a new sector and generate jobs and growth.

Future Potential

Clean Energy | UK Competitiveness

- **68,000 jobs** — Floating offshore wind, tidal stream and wave energy could generate 68,000 UK jobs by 2040 [4]
- **£86bn GVA** — And unlock over £86bn in GVA to the UK economy by 2050 [4]
- 50% of the GVA & jobs comes from manufacturing the generating devices [4]
- Offshore Wind in the UK could exceed 43-50 GW by 2030 [2]
- Predictable ocean energy can save the GB energy system £1bn annually by 2050 [39]

With targeted research to address the identified challenges, together with sustained support and connection across the ORE innovation landscape, we can look forward to further success for the UK.

Key Takeaways of the Strategic Research Agenda

The SRA sets out the priority agenda for the underpinning research necessary in the next 5 years to advance the ORE sector in the next 25 years. In order to achieve UK Government ambitions towards clean power and economic growth and in the longer term, Net Zero, we recommend:

- Supporting underpinning research in areas set out by the SRA.
- Combining efforts to benefit from synergies across offshore wind, tidal stream and wave energy.
- Establishing and maintaining sustained and connected research, innovation and industrialisation pathways.

Consulting this document will enable:

- **Policy makers to create** a connected pathway of research, innovation and UK industrialisation interventions aligned with Sector Plans and Taskforce findings to ensure climate and economic ambitions are achieved;
- **Funders to design** connected programmes and target specific calls to provide joined up funding routes for the sector;
- **Industry to combine efforts,** leverage funding sources and benefit from academic research expertise and facilities;
- **Researchers to develop** research projects with tangible outcomes and impact within the wider ORE landscape.

Decisions made today on which priority areas to pursue, which research challenges to address, and where to direct investment, will shape the technologies, industries and capabilities developed in the UK over the decades ahead. By establishing a shared understanding of these priorities, the SRA provides a foundation upon which researchers, industry, funders and policymakers can coordinate their efforts and maximise the contribution of ORE to the UK's future clean energy and economic growth ambitions.

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