Supergen

Offshore Renewable Energy

Core Research

2023 - 2027

Engineering and Physical Sciences Research Council

Background and context

Rapid Offshore Renewable Energy (ORE) expansion is essential to the UK for Net Zero and climate change mitigation, energy security, and green growth and jobs.

- Climate change mitigation: requires ORE to be deployed 10 times faster than the current rate to meet Net Zero targets set out in the 6th Carbon budget. If we are to meet the UK plans for Net Zero, Energy Security and just transition, there needs to be a significant ramp up in underpinning research and in skills and training – it cannot be business as usual.
- Energy security: ORE growth will mitigate the effects of the cost-of-living crisis and geopolitical instability. ORE can minimise consumer energy costs, but many research and engineering challenges need addressing to realise the scale and rate of deployment required. A fourfold reduction in project consenting time is targeted, requiring a whole system approach with interdisciplinary collaboration underpinned by an integrated research and innovation.
- Green growth and jobs: The UK's ORE industry growth underpins new high-skilled jobs, often in areas of the UK in most need of investment, supporting the levelling up agenda. With a local and abundant resource, rapid expansion of ORE for Net Zero could help to achieve a Just Transition with economic and social benefits, keeping the UK as a world leader in deployment and technology for ORE.

High level objectives

With an increased focus on delivering and enabling impact, the Supergen ORE Hub will drive faster ORE expansion via four high level objectives:

1. *Streamlining* ORE projects, by accelerating planning, consenting and build out timescales
2. *Upscaling* the scale and efficiency of ORE devices and systems, and the ORE workforce
3. *Competitiveness*: maximising ORE local content and ORE economic viability in the energy mix, to maximise UK benefits of the drive to Net Zero
4. *Sustainability*: ensuring positive environmental and societal benefits from ORE; a just transition

Workstream overview

The first phase of the Supergen ORE Hub has built a community of academics, industry and other stakeholders, successfully unifying the ORE community around common research challenges. The next phase will build on all elements of the established structure and take this activity and impact to the next level to match UK Net Zero, Energy Security and affordability aspirations.

The new work programme addresses the key drivers of streamlining, upscaling, competitiveness and sustainability through five interdisciplinary workstreams:

Workstream 1: ORE expansion – policy and scenarios: explores future upscaling scenarios and the enabling policies required to ensure economic and system benefits, enabling retention and growth of domestic supply chains, skills and circular economy, as well as methods to include ecosystem benefits in GVA measures, facilitating sustainability, ORE's contribution to Net Zero and a just transition.

Workstream 2: Data for ORE design and decision-making: advances in data collection, collation, analysis and interpretation will streamline and accelerate design and decision-making in ORE projects, from the planning and consenting phase, through operations, to the end-of-life outcomes.

Workstream 3: ORE modelling: upscaling will require more advanced modelling tools addressing more complex applications. Confidence in new tools, approaches and computing architectures requires the quantification of uncertainties through targeted development, experimental validation and aligned field measurement campaigns.

Workstream 4: ORE design methods: new design solutions and new design methods will help achieve cost reduction and improve competitiveness needed to accelerate technologies in offshore wind, tidal and wave infrastructure.

Workstream 5: Future ORE systems and concepts: novel frontier sustainability solutions to achieve step change advances in ORE though sharing infrastructure, multi-use and multi-turbine structures and very large and interconnected floating systems.

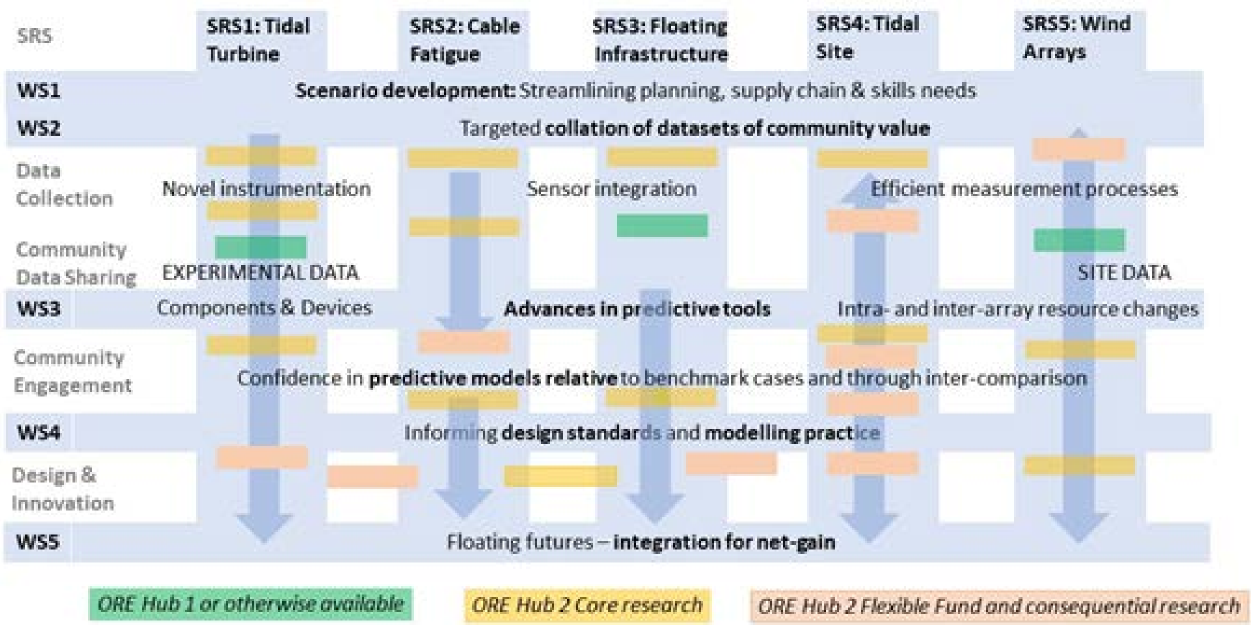
Supergen Representative Systems

Outputs from the interdisciplinary Workstreams feed into Supergen Representative Systems (SRS) established to achieve:

- Academic and industry community engagement
- Comparative reference cases for testing and comparing modelling tools and approaches
- Assessing the applicability of emerging technology to existing standards and codes and making recommendations for updates and data gaps
- Assessing data processing techniques and packaging to provide informative and de-sensitised datasets

SRSs will be shared with the community as open metadata sets, and will be built on through core research, Flexible Funded projects and other ORE research engaging with the Supergen ORE Hub. Outputs of the Hub research will be produced as White Paper deliverables containing position papers, synthesised research and policymaker advice.

Five SRSs (Tidal Turbine, Cable Fatigue, Floating Infrastructure, Tidal Site and Wind Arrays) will be defined to align research activities towards the development of multi-scale simulation tools and their validation and integration with real datasets, targeted to address key sector challenges.



These SRSs will aid the development of codes and standards for ORE design and will be developed from core research workstreams as indicated in the workstream description and workplan, and will be utilised for community benchmarking and code comparison activities to:

- Increase confidence in high-fidelity modelling tools, with a particular focus on predictive capabilities to inform engineering design & planning.
- Quantify and reduce key sources of uncertainties affecting design, environmental impact, project risk, investor confidence, cost reduction.
- Generate an evidence base and assess the applicability of standards to emerging technologies in ORE.

For each SRS the focus will be on developing digital tools in tandem with datasets and data analysis tools, although the stage of development of models and datasets may differ. In some systems the focus will be on advancing modelling of a real (physical) system, including development of controlled experiments and of measurement techniques. However, for others the focus will be on developing a high-fidelity numerical model (or coupled-set) for a reference system prior to full availability of real (physical) data for the same system. This would inform the development of data collection, data analysis and data integration methods.

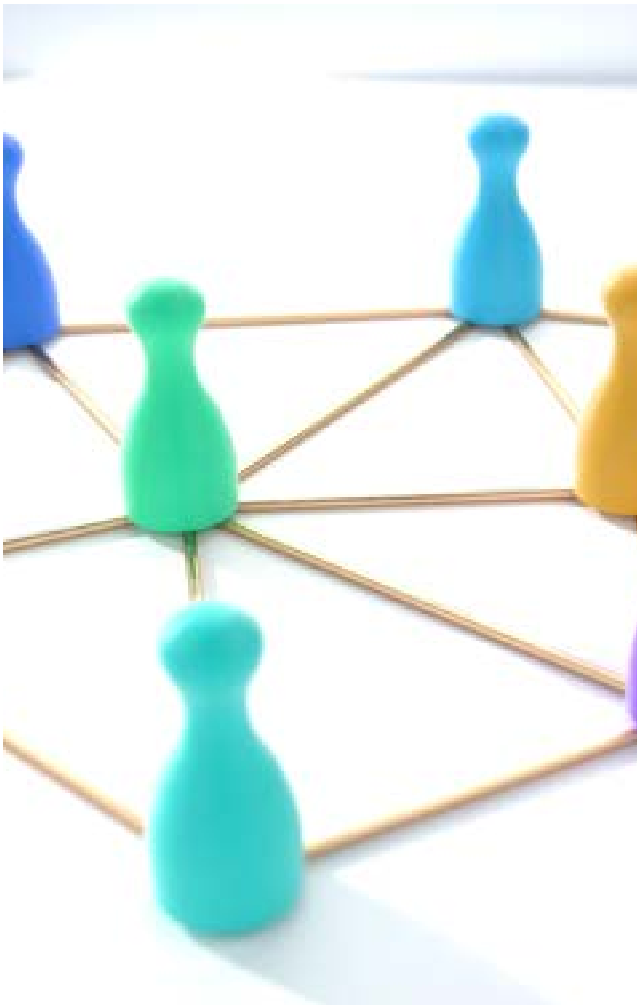
The SRS may form the basis for digital twins for the ORE sector. However, they are not intended to be fully developed within the timescale of the Hub, or solely by the Hub team. Instead, the intent is to identify systems that can be used as the basis for developing the framework, modelling and data collection, analysis and integration techniques that can accelerate adoption of digital tools by the sector to de-risk rapid deployment.

Workstream 1

Offshore Renewable Energy Expansion – Policy and Scenarios

Overview

Workstream 1 builds on from Work Page 1 of Supergen ORE Hub phase 1, which published several policy papers, analysing the benefits of UK ORE deployments to the economy and electricity system operation and the overall policy mechanisms required to support ORE. This Supergen ORE Hub phase 2 workstream focuses on the enabling policies required to realise these benefits, with respect to supply chain, skills and circular economy, aiming to facilitate ORE's contribution to Net Zero and a just transition.



Tasks

- **Supply chain and skills policy requirements for Net Zero:** will investigate and analyse requirements for a competitive ORE supply chain, with a high UK retention of goods and services.
- **Roadmap for upscaling ORE within the circular economy:** will analyse the key opportunities for ORE deployments to contribute to a sustainable circular economy.
- **Recommendations for streamlining of consenting policy:** will investigate recommendations for streamlining of future consenting processes, by providing an international and cross-sector review of best practice for these processes.
- **GVA with net gain:** Building on the ecosystem-based natural capital approach developed in phase 1 that accounts for the multiplicity of interactions between physical processes, biological indicators and anthropogenic marine use (i.e. fishing), Phase 2 will test this framework in AR4 and ScotWind sites.

Workstream 2

Data for Offshore Renewable Energy Design and Decision-Making

Overview

A key barrier to streamlining and growth of ORE is the length of the planning and design timeline, particularly in new regions of development. This timeline is affected by the volume and duration of data gathering through surveys and monitoring, as well as the modelling required to underpin planning and design decisions. Solutions to this challenge include better coordination at inter-farm and regional scales through sharing of data and analysis, as well as technological and simulation innovations that provide the required data and insight more quickly and efficiently.

This workstream addresses the gathering technologies, analysis methods and curation strategies for ORE site and system data. WS2 has two focus topics that form the themes of this workstream:

1. Data-driven opportunities to streamline ORE project planning, design and development
2. Datasets of ORE frontiers to inform research, planning and technology development

Tasks

- **Data-driven opportunities to streamline ORE project planning, design and development:** Supergen ORE Hub Phase 1 supported a range of developments for ORE data gathering and site characterisation, including technologies for environmental and geotechnical sensing. Workstream 2 will expand this effort, including: co-collection of data for predictive models that can be used for metocean and seafloor characterisation and ecological impacts, strategy development to optimise instrumentation and measurements required to underpin engineering and ecological forecasts for project planning, and novel technologies for seafloor characterisation, including cable routes, bypassing the latency of onshore lab testing.
- **Datasets of ORE frontiers to inform research, planning and innovation development:** Supergen Hub Phase 1 established a baseline forecast for UK ORE deployment scenarios required to meet different Net Zero scenarios through a GIS-based mapping activity. This study identified the changing environmental, seafloor and co-usage/co-location conditions that will be encountered. Phase 2 will build on this platform by focusing on key new ORE development regions.

Workstream 3

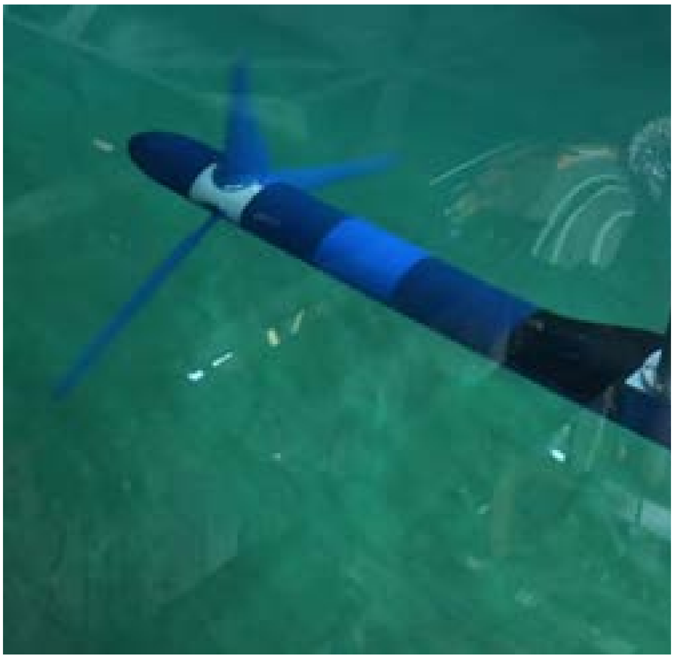
Offshore Renewable Energy Modelling

Overview

The increasing scale and rate of deployment of ORE gives an opportunity to reduce reliance on learning via field deployments by improving capability of modelling techniques through targeted development, experimental validation, development of best practice, and aligned field measurement campaigns.

Tasks

- **Unsteady load prediction for tidal turbine design: accelerating cost-reduction:** Phase 1 development of the ORE reference tidal turbine has provided a unique highly instrumented test-platform and dataset that has enabled community engagement. Experiments will now be undertaken to advance load prediction in two types of *unsteady* onset condition: steady yawed flow, to generate periodic variation of onset flow to each blade during rotation, and surface waves, to generate both temporal and spatial variation of the flow incident to the rotor.



- **Array energy yield predictions and siting – enabling array planning for scale-up:** High fidelity CFD models will be advanced to analyse wake recovery for conditions representative of candidate deployment sites. An LES solver will be employed with bathymetry from public sources, or under license, generic turbines inflow conditions around domain perimeter informed by pre-cursor resource simulations or site measurements. Building on the ORE turbine community engagement approach, prior studies of wakes of small arrays in idealised conditions, an experimental campaign will be designed to reduce the major uncertainty in tidal array energy yield.
- **Physical processes affecting ecosystems** – *accelerating consenting for Net Zero targets:* Advances in ecological analysis methods in Phase 1 have enabled integration of predicted, and measured changes of physical processes into multi-year statistical predictions of ecosystem dynamics. Phase 2 focuses on accurate prediction of changes to physical processes due to ORE systems and infrastructure at appropriate scales (typically ~10 min, >1km), particularly for conditions and locations which have been identified to affect population trends, or Net Gain.

Workstream 4

Offshore Renewable Energy Design Methods

Overview

Workstream 4 addresses design challenges to accelerating impact from ORE technologies, which include assessing whether the inherited design standards and codes, tools and methods are fit for purpose for current and future ORE, and developing new design solutions for frontier systems and sites. Determining survivability and reliability of ORE structures is crucial before deployment into the ocean, and accurate and efficient modelling of wave-structure interactions is vital to support ORE design and performance evaluation. Floating ORE devices often exhibit large dynamic and nonlinear responses meaning that high-fidelity modelling approaches are needed.

Tasks

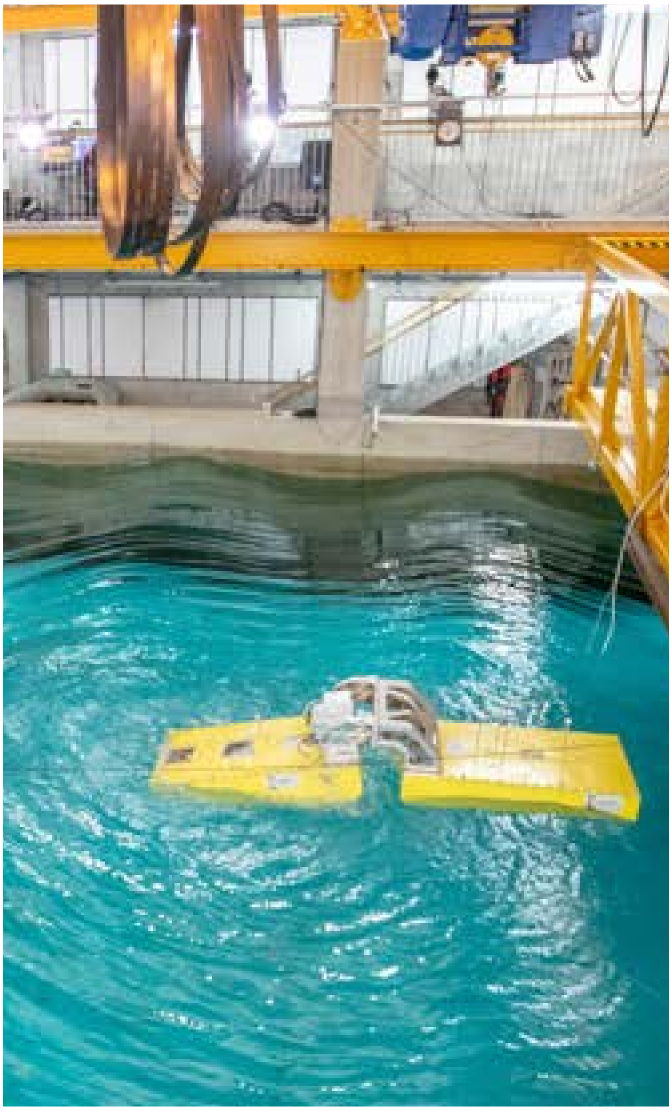
- **Optimising geotechnical models for ORE Design:** approaches that can efficiently process site characterisation data and loading actions through response models to optimise geotechnical reliability, capturing the critical loading events and whole life behaviour, particularly for new frontier systems and sites will be investigated. Optimised design approaches for variable site conditions including seabed materials, geology, bathymetry, wave and wind will be developed.
- **Design wave approaches for ORE:** using short design waves (SDWs) to produce an extreme response can bypass long-duration irregular sea state simulations. Here, SDW methods developed in phase 1 will be extended to include turbulent wind, currents and complex wind-wave-current misalignment scenarios, utilising recent advancements in aerodynamic emulation and blown wind experiments. Equivalent SDWs for wind gusts will be investigated and design parameters assessed.
- **Risk-Based Design for cabling systems:** will be used to demonstrate the suitability of innovative dynamic cables for the range of current and future floating wind concepts. Sensing systems will be developed for components of wind and tidal systems to explore dual use for monitoring of environmental and ecological impacts.

Workstream 5

Future Offshore Renewable Energy Systems and Concepts

Overview

Workstream 5 focusses on a range of fundamental considerations and low technology readiness level (TRL) future ORE systems and concepts. The considerations range from ocean space utilisation and sustainability, safer and more circular use and operation of infrastructure and materials, through to seabed interaction, power integration and wave energy membrane concepts.



Tasks

- **Power density:** In phase 1 significant progress was made to better understand floating foundations and in particular how VLFS (Very Large Floating Structures) can be modelled, and the opportunities associated with foundation systems that support multiple turbines. This theme will continue by focussing on the potential for floating systems to be configured for more dense power production through floaters supporting multiple turbines/devices including flexible membrane based WECs.
- **Longevity and Resilience Design Philosophies:** considers how offshore structures, ancillary equipment and components can be designed to support offshore energy applications for extended periods i.e. potentially up to and beyond fifty years.
- **Resilient onshore and support infrastructure:** Multipurpose infrastructural designs and the use of digital platforms to virtually examine through simulation and therefore optimise through-life circular aspects will be studied and potential assessed.
- **Power Integration:** investigating the impact of increased penetration of offshore wind farms (OWFs) on the short circuit level (SCL) of the connected grid, and developing mitigation measures to address the SCL-associated instabilities due to high penetration of OWFs.

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