CIRCUIT

CATAPULT
Offshore Renewable Energy

ISSUE 11 // AUTUMN 2017

FOUNDATION INNOVATION

SUPPORTING NEXT GENERATION OFFSHORE WIND FARMS

FEATURES

// Floating wind financials
Opening up new offshore wind resources

// Next generation foundations
Supporting the wind farms of the future

// HV Materials Lab
Leading electrical systems and materials R&D

(Image courtesy of **EDF Energy Renewables**)

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Offshore Renewable Energy

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WELCOME

Guest foreword – Emma Pinchbeck, Executive Director, RenewableUK

Emma Pinchbeck

The last few months of 2017 have seen the UK's offshore wind sector come into its own. This young, ambitious industry has reached maturity – with prices tumbling, another 3GW-plus of installed capacity consented, and a third of the UK's electricity now being generated by renewables, largely thanks to wind power. Offshore wind is now one of the UK's cheapest forms of large-scale, clean electricity – cheaper than new nuclear and gas.

In early November across the country, we are celebrating Offshore Wind Week. A chance for the industry to showcase the dramatic advances in technology innovation and cost reduction it has achieved, and its vital role at the heart of the UK's future energy needs, contributing billions to the UK economy and generating thousands of jobs.

There is no doubt that the industry's success is due, in large part, to its relentless focus on innovation to bring down costs. And as wind farms move into deeper waters, and developers are able to harness previously inaccessible wind resources, the need for continued innovation in turbine foundations is more important than ever to help exploit these new opportunities.

Traditional wind farm foundations and substructures, and their associated deployment methods, must evolve to meet the challenges of anchoring larger turbines in more challenging seabed conditions.

Floating wind is an exciting new frontier in technology development that the offshore wind industry is embracing. Our inaugural floating wind conference in November will bring together all those involved in the sector to discuss the substantial opportunity floating wind technology represents for supply chain companies and the global industry. Many of these innovative foundation concepts are on the brink of moving from demonstrator projects to commercial viability. I'm in no doubt – the evolution of floating offshore wind is a massive economic opportunity for the UK over the coming decades.

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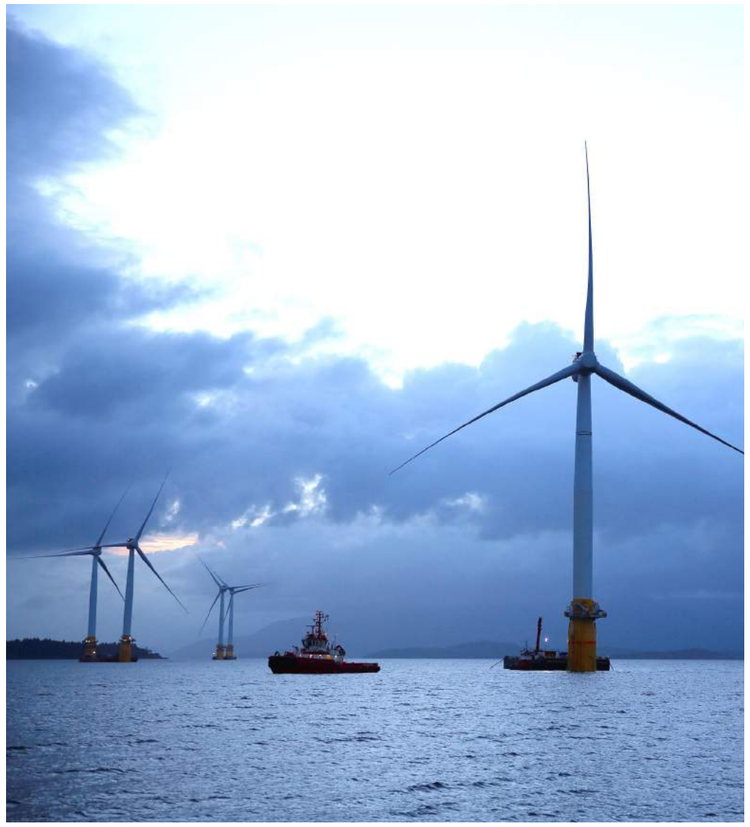
THE FINANCIALS OF FLOATING WIND

Not so long ago, floating wind was an idea confined to the whiteboards of ambitious academic researchers. As the technology has matured, enabling small-scale prototype projects and the world's first pre-commercial array, it has become clear that floating wind farms are the key to opening up enormous new wind resources in expanses of water too deep for conventional, bottom-fixed farms.



This makes it an important area of research for the industry. But as with many new technologies, one of the biggest obstacles standing in the way of full-scale floating wind commercialisation is cost.

Trial projects like the WindFloat project in Portugal, the FORWARD project in Japan, and Hywind in Scotland have yielded progress. But floating wind still lags far behind bottom-fixed wind in terms of commercial readiness, and government support will be required in the medium term if, as predicted, it is to achieve or outstrip the cost reduction that has been witnessed in bottom-fixed offshore wind in recent years.

There are three common types of floating wind substructure: semi-submersible, spar, and tension leg platform (TLP). By analysing the costs associated with building a floating wind farm using each typology, and comparing them to that of a bottom-fixed monopile offshore wind farm, it's possible to gauge how far away floating wind is from reaching financial parity.

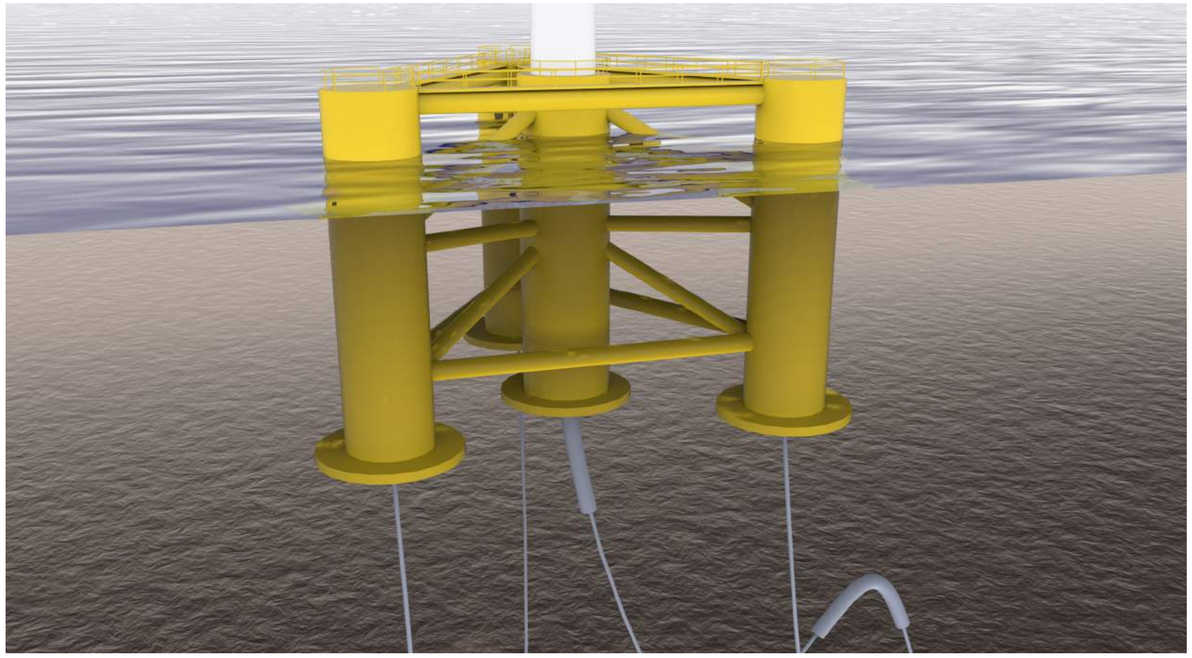


image above
Semi-submersible floating foundation

image left
Hywind Scotland

Let's look at the cost of building a floating wind farm, broken down into key project stages:

Development and Consent

The cost of developing and consenting a floating wind farm is expected to be slightly less expensive than a bottom-fixed. Shallower bore samples – with a possible exception in the case of TLP technology – when conducting geotechnical surveys could potentially contribute to these savings. However, with multiple anchors, more samples would be required.

Turbines

The turbines used in bottom-fixed and floating situations are nearly identical. Both use adapted onshore machines, and modifications are made to the blade pitch control algorithms for floating turbines. This makes floating turbines cost-equivalent when compared to bottom-fixed.

Substructures and Mooring Systems

Compared to monopiles, substructures for floating wind turbines are, for now, considerably more expensive to manufacture and assemble. Steel substructures are many times heavier and more labour-intensive to put together, whereas concrete substructures are cheaper per tonne of material but considerably heavier. In addition, all floating wind turbines require mooring lines and anchors.

Mating

Attaching the turbines to their substructures is one of the areas where floating wind has a clear cost advantage over bottom-fixed: turbines can be installed in a much more controlled environment, and without the use of expensive jack-up vessels. However, spar technologies require deep, sheltered waters and offshore cranes, resulting in a mating process that is more costly than semi-submersibles and TLPs.

Array Cables

Array cables for floating wind are currently more expensive, as they require dynamic cables (umbilicals) and bespoke electrical connectors, of which there is a limited availability. However, they can be installed before turbine installation, allowing multiple processes to be performed in parallel.

Installation

While more vessels are required for floating wind installation compared to monopiles, these are considerably cheaper to charter than a jack-up vessel. An exception would be in the case of TLPs that, if not self-stable in towing, require bespoke installation barges, which would incur significant expenditure.

Transmission

Higher transmission costs for floating wind come from the necessity of putting an electrical substation in deep waters. While this could take the form of a fixed or floating platform, a floating solution would require the development and qualification of very high-power dynamic cables, which are currently not available on the market.

O&M and repairs

Costs for O&M and minor repairs are expected to be very similar to current bottom-fixed costs. Tests have demonstrated the applicability of crew transfer vessels (CTVs) used in bottom-fixed offshore wind to floating turbines and in the case of concrete substructures, inspection frequency could be reduced. Costs for major repairs will vary by typology and the process is, in essence, a reversal of the installation procedure: semi-submersible structures can be decoupled and towed back to port for repairs, making them cheaper than offshore repair work for bottom-fixed. Bespoke equipment for TLPs and spars erode the cost advantages compared to bottom-fixed.

Decommissioning

Decommissioning costs for floating wind turbines are expected to be lower than for bottom-fixed. This is particularly true for semi-submersibles that do not require bespoke equipment or heavy lift operations offshore.

In general, costs are reduced compared to bottom-fixed in areas where operations can be performed onshore rather than offshore. Even for the offshore operations, less-complex, more readily-available vessels are required during mating, O&M and decommissioning.

Ultimately, cost will determine whether floating wind sinks or swims. Reductions will be driven by the development of specific components and enabling systems, techniques and infrastructure, such as electrical connections and bespoke vessels and port facilities. But with continued innovation as the technology matures, there are no areas where floating turbines will be materially more expensive than bottom-fixed. Floating wind has a buoyant future ahead.

NEXT GENERATION FOUNDATIONS FOR OFFSHORE WIND

In July, the dramatic images of Hywind's turbines being towed across the North Sea captured imaginations beyond the world of offshore renewables.

Statoil's project, off the coast of Peterhead in north-east Scotland, is the world's first floating wind farm, with first power generation from its 175m-tall turbines making headlines across the world.

It brought floating wind into the national consciousness for the first time, but the Catapult's researchers have been working on innovative new foundation solutions for several years.

We're a key partner in LIFES50+, a European Horizon2020-funded project focused on proving the innovative technology that's being developed to enable floating substructures for 10MW turbines to be deployed in water over 50m deep.

With larger, 10MW-plus turbines key to reducing the cost of energy generated from offshore renewables, our engineers are leading on the uncertainty and risk management aspects of the project.

"We started by evaluating the risks associated with the development of the floating wind substructures," says Roberts Proskovics, an Engineer in the Catapult's Operational Performance team. "We then designed and developed a risk assessment methodology for the substructures, drawing on good practice for risk assessment and management while remaining flexible enough to apply to different types of risk at all stages of the technology's lifecycle, from design to decommissioning."

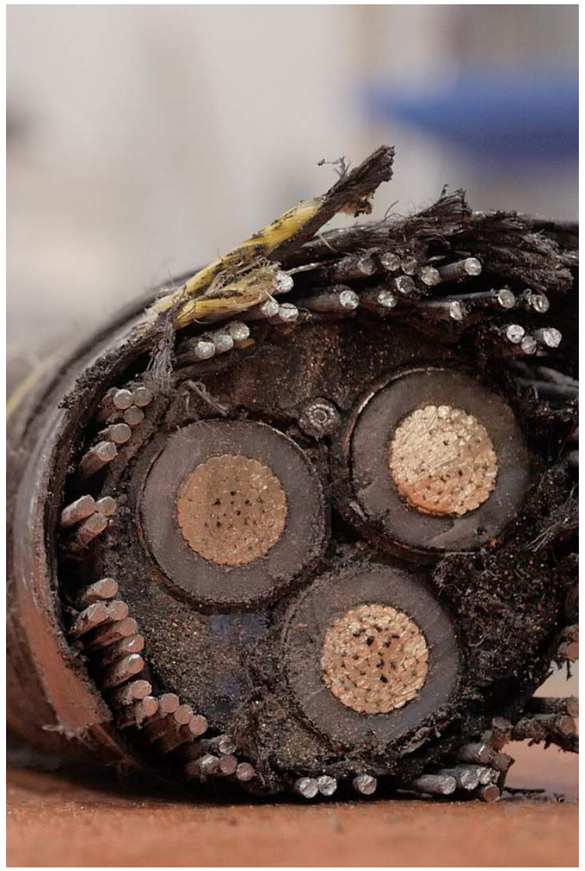
And as part of the Demowind-funded FS Found project, the Catapult is partnering with Blyth Offshore Demonstrator, EDF Energy R&D UK Centre and BAM Wind Energy JV to demonstrate and validate revolutionary "float-and-submerge" gravity-based foundations (GBFs) at the Blyth Offshore Demonstrator Wind Farm. It's the first full-scale wind farm to deploy GBFs, and two of the wind farm's five foundations have been fitted with a groundbreaking sensor system designed by the Catapult.

"Our part in the project is two-fold," says Jonathan Hughes, the Catapult's Technical Lead on the project. "First, we're looking at how the foundations perform: making sure they are doing their job, and performing as they were designed to out in the field. Secondly, we're looking at how we might carry out prognostics and diagnostics on this kind of foundation in future. This is key because we already know how monopiles work – we have ways to calculate their fatigue life and the loads they sustain. But we need this data on gravity-based foundations to improve design optimisation and reduce costs, helping to make them commercially viable as a foundation solution."

image above
Float and Sink GBFs installed at the Blyth Offshore Wind Farm (image courtesy of EDF Energy Renewables)

HV MATERIALS LAB: SHAPING THE INDUSTRY'S ELECTRICAL FUTURE

Electrical infrastructure makes up almost a fifth of the lifetime cost of an offshore wind farm. This, coupled with insurance claims arising from cable failures, makes electrical systems and their associated materials a leading area for technology research and innovation to drive down the cost of energy.



In our Charles Parsons Technology Centre in Blyth, ORE Catapult operates the UK's only state-of-the-art, open-access high-voltage (HV) insulation materials laboratory for the testing and validation of HV insulation materials used in offshore renewables projects.

We partner with key sector players to understand their future testing needs and, as part of a continued programme of investment to keep our assets at the forefront of industry requirements, the lab has recently been refurbished and enhanced with a cutting-edge suite of spectroscopic and microscopic systems, helping our scientists carry out atomic-level characterisation and forensic analysis on the materials that make up offshore power systems.

"You need to know what a material's made up of, how strong it is, how it performs, and whether it's meeting its specification," says Lee Harris, the Catapult's HV Materials Engineer and the man in charge of the day-to-day running of the lab.

"The next generation of offshore wind farms will need to keep generating reliable electricity for their entire lifespan, which is expected to be around 25-40 years," says Lee. "For that to happen, the cables that connect the turbines to each other and to the substations are going to have to withstand enormous loads and remain operational in the harsh conditions you find in deep water far offshore."

The Catapult helps ensure that its clients' materials are up to that task by putting them through highly-accelerated life testing (HALT) – the process of subjecting something to years' worth of operational conditions in a condensed period of time, allowing faults and weaknesses to be exposed before the product goes into the field.

For subsea cable manufacturers, that's especially important because of the cost of repairs once cables are installed. "Factor in turbine downtime," says Lee, "plus the cost of cables, trenching equipment, vessels and personnel and it can cost £2-5million per km. A fault, such as a cable short-circuit, could prove massively costly for developers: insurance claims relating to cable failure alone cost the industry £60m per year.

image above
Lee Harris undertaking materials analysis

image left
Cabling

"There's a lot of research currently being performed on the performance of cables, how the water ingresses and diffuses over time, and how that affects the cable's insulating layer quality. One way that cables break down is due to what's known as a 'water tree,' so analysing these is a major part of that research."

Water trees need only be microns wide to cause a short circuit, and they only form when the water content of a cable's insulating compound reaches a certain level. "That's why it's so important to know the water content," says Lee. "It's only when it's above around 70% that you start to get breakdown effects.

"Carrying out that water tree characterisation gives us an understanding of the condition of the aged insulation and helps us confirm that the insulating layer is high-quality, which in turn helps to keep down the lifetime costs of the offshore wind farms using those cables."

The laboratory also carries out forensic analysis of materials, with the capabilities to analyse why a breakdown has occurred and factor in the wider set of circumstances leading to a failure.

One unique feature of the Materials Laboratory sets it apart from competing facilities: it's the only open-source, UKAS-accredited lab in the UK with the capability to carry out the full ageing and materials analysis workflow under one roof. That presents a huge advantage for cable manufacturers seeking certification for their insulation products via hot set testing, a process required for conformance to international cable standards. It looks at how strong the insulating material's bonds are.

"These cables," says Lee, visibly enthused as he points towards an ageing tank in the Catapult's HV lab, "will be in this tank for two years undergoing highly-accelerated testing. As soon as we remove the cable from the water, the insulating material starts to push water out – that's the nature of the compound. So, as per international standards, hot set testing has to be carried out within 15 minutes of the cable leaving the tank.

"With the Materials Laboratory and the HV lab together, it makes our facility the only open-source, UKAS-accredited facility in the country that can carry out that electrical ageing and then materials analysis within the allotted time.

"We've worked on projects with both large multinationals and smaller, local companies – open-source labs like this offer a lifeline to companies who don't have the facilities to carry out these tests themselves. And we have a really strong combination of electrical and materials testing ability that allows us to develop full-workflow solutions.

"In fact, there are few other open-source laboratories in the world with the capabilities that we have here."

FUTURE BLADES UP FOR DISCUSSION IN BLYTH

In September, leading offshore wind farm developers, turbine blade manufacturers and researchers gathered in Blyth to attend a major industry conference to address key challenges in the test and certification process for offshore wind turbine blades.

image above
Conference guests witnessing a blade inspection

image below
BladeBug inspection device

The two-day conference was hosted at our National Renewable Energy Centre in partnership with Danish blade strengthening specialists Bladena, on behalf of a European blade network made up of wind turbine operators.

The event brought together developers and manufacturers with world-leading research institutions to discuss the latest challenges in wind turbine blade testing, validation and certification and the latest research and innovations being developed to tackle them. Specific topics for discussion included blade testing and type certification requirements that go beyond existing standards and technical requirements around blade design, manufacturing, materials, testing, repair and operations.

One area that received particular focus was bi-axial testing, and the impact it could have on the testing of full-scale blades in future. For static testing, the single axis tests that are performed as part of the certification process are often not representative of the worst case scenarios the blade will experience in service. Therefore, applying combined loading will result in a more conservative test.

Leading test experts, including representatives from Blaest, DTU, Fraunhofer, WMC and ORE Catapult, presented to wind turbine owners on the benefits of bi-axial testing, providing them with an in-depth understanding of the process in response to calls to understand how these more rigorous tests could help to reduce failures in the field.

ORE Catapult's Peter Greaves, who presented his research on bi-axial testing, commented: "Bi-axial static testing is relatively straightforward, but this conference showed that several European test centres are nearing readiness to perform bi-axial fatigue testing on large blades. Bi-axial fatigue testing is much more representative of the loading that blades are exposed to in service, so it is more likely to identify design flaws before the blade is put into service. This will help to reduce failures in the field, which will help to reduce operations and maintenance costs."

Bladena's Chief Technical Officer, Find Mølholt Jensen, said: "It is interesting to see the latest developments that European test centres have achieved in full-scale testing with combined loading. This way of testing is possible today statically but is a challenge dynamically for very large blades. With the knowledge that has been shared at this seminar I believe that it is possible to promote this process in the future."

Overall, the event was a success - industry attendees had the opportunity to engage in open dialogue across a number of key issues in blades, and learn more about solutions for overcoming the challenges the industry may face in future.

E.ON's blade specialist Birgit Junker said: "This wind turbine owner network is of great importance to us as we are able to have technical discussions with a number of like-minded colleagues and experts, such as test, innovation and research centres. The importance of increasing the requirements for full-scale testing is essential to reduce the risk of blade damages, especially as the size of the blades increases."

ORE Catapult's Test Facilities Director Tony Quinn added: "The seminar has helped to give a better understanding of the issues affecting blade performance and explored the opportunity for improved design and more representative testing – developments that are important in further reducing the levelised cost of energy from offshore wind."

PROJECT SNAPSHOTS

EnFAIT

With a global ocean energy market worth £76 billion, it's estimated that marine energy could contribute billions to the UK economy by 2050, creating jobs and growth opportunities.

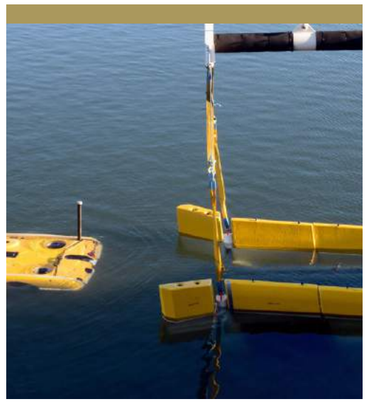
A flagship €20.2m EU Horizon 2020 project, led by Nova Innovation and supported by the Catapult and seven other industry and academic partners, aims to accelerate tidal energy's journey towards cost-competitiveness with other sources of offshore renewables generation. EnFAIT (Enabling Future Arrays in Tidal) kicked off in July 2017, and will expand Nova's existing Bluemull Sound site off the Shetland Islands, creating what will be the world's largest power-producing tidal array.

The project will use 100kW turbines, allowing a variety of array configurations to be investigated. The Catapult's role involves working on hydrodynamic modelling, focusing on array optimisation, and the communication and dissemination of the project's successes and how they relate to the wider industry.

Offshore Wind Innovation Hub

Bringing industry and government together to help UK businesses seize opportunities in offshore wind is the work of the Offshore Wind Innovation Hub, which launched in May 2017. Funded by the Department of Business, Energy and Industrial Strategy (BEIS) and delivered jointly by the Catapult and Innovate UK's Knowledge Transfer Network, the Hub exists to shape a more coordinated approach to innovation in the sector.

Based on the principles of being impartial, inclusive and trustworthy, the Hub's mission is to consult and convene industry to define the sector's innovation priorities, inform government of those priorities, and optimise the industry's response to funding calls most effectively while promoting successes domestically and internationally. Its first programme, the Offshore Wind Innovation Exchange, is a cross-sector scheme accelerating cost reduction by matching innovation challenges with solutions adapted from other sectors.



AVISIoN

The cost of surveying the seabed and inspecting subsea cables and foundations represents a major challenge for the offshore wind industry. Inspections and surveys using vessels, technicians and divers are expensive and high-risk, creating a significant market opportunity for disruptive solutions that are cheaper and less risky.

The AVISIoN (Autonomous Vehicle for Inspection of offshore wind farm Subsea INfrastructure) project, led by Darlington-based Modus Seabed Intervention, will develop, test and demonstrate an autonomous underwater vehicle (AUV) for inspecting cables and substructures. Modus and the subsea SME Osbit will develop existing AUV hardware to improve its suitability for offshore wind, while the Catapult's dry docks and NOAH met mast will allow the AUV to be tested and demonstrated in real-world conditions. The project is expected to contribute to a 0.8% reduction of the levelised cost of energy (LCoE) of offshore wind.

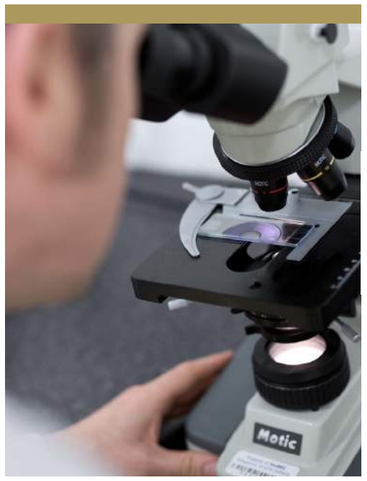
Knowledge | Collaboration | Innovation

RECODE

The commercial success of wave and tidal energy will depend heavily on the development of reliable, cost-effective generation technologies.

By developing, demonstrating and validating a common set of four critical components for ocean energy devices and arrays, the RECODE project aims to catalyse cost reduction in the sector. The components being developed include a safety monitoring and control device, a wave measurement buoy, an umbilical cable monitoring device and an underwater device-to-cable connector for a floating energy converter.

By rolling these common components out to marine energy technology developers, the considerable time and cost of developing bespoke parts is saved, allowing resources to be channelled into generation technologies.



International Research Platform

With almost 36% of the world's installed capacity, the UK is leading the way in offshore wind. The opportunities to export the expertise built up in the deployment of that capacity are enormous, and few are bigger than in China, where the government plans to invest $100 billion in offshore wind over the next five years.

The Catapult's International ORE (offshore renewable energy) Research Platform will create a focused programme of international industrial research engagement, offering support to offshore wind developers in China and the US and helping companies in the UK build partnerships and drive growth.

The project will engage with bodies in the UK, China and the US to find gaps where high-tech UK solutions can be applied and areas for further research, and seek to secure investment that will help British companies commercialise technologies for the international supply chain.

SMART

A new product's route to market is often hampered by a lack of readily-available test and demonstration facilities, with wind farm owner/operators understandably reluctant to incur asset downtime to test novel, unproven technology.

The follow-up to the Scottish Government-supported CLOWT (Clone of the Levenmouth Offshore Wind Turbine) project, SMART (SME Asset Research and Testing), offers further research and demonstration opportunities for innovative SMEs with the potential to positively impact the development of the Scottish offshore wind supply chain.

Expanding the original project's scope beyond sensors and instrumentation, SMART will give those companies precious real-world demonstration time on the world's largest open-access offshore turbine dedicated to research. In addition, the Catapult will help companies with less-developed technologies to advance their products, and share turbine data to support academic research projects.

NEWS ROUND UP

Hull to host O&M Centre of Excellence

A new £2 million collaboration between the Catapult and the University of Hull will see the launch of an offshore wind Operations and Maintenance (O&M) Centre of Excellence in the Humber region.

The five-year partnership will see a series of research and innovation projects developed to improve the way that offshore wind farms are operated and maintained, building on the region's energy heritage, location and experience of servicing UK offshore wind farms.

The Humber Estuary has extensive experience of servicing offshore wind farms," said Chris Hill, the Catapult's Operational Performance Director. "That experience is invaluable as we look to build expertise and a local supply chain, establishing the region as a real centre of excellence that can service UK offshore wind farms as well as exporting to the fast-growing international market."

Science and Innovation Audit identifies strong economic and job opportunities

A newly-published audit has highlighted Scotland and the North of England's strong contribution to the UK's position as a global leader in offshore renewables innovation.

The Offshore Renewable Energy Science and Innovation Audit (SIA), commissioned by the Government to set out the UK's strengths in key areas, evidenced the area's world-class research facilities, strong supply chain, and the many innovation programmes and collaborations between industry and academia.

"This report is vital in supporting the forthcoming offshore wind sector deal to Government and proves confidence in the future of our sector," said Dr. Stephen Wyatt, Research and Innovation Director at the Catapult. "A strong science and research base provides the support framework needed to allow UK businesses to flourish, creating jobs and economic benefit and attracting inward investment."

£600k makeover gives historic docks a bright future

Work is underway on an ambitious project that will see Blyth's historic docks receive a £600k makeover. The removal of a 70-tonne dry dock gate represents the first stage of the investment programme, which will help maintain the docks' legacy of groundbreaking innovation.

The Port of Blyth, which dates back to the 1100s, has a heritage of being home to maritime pioneers. Legendary mariner William Smith called Blyth his home port, while the world's first modern-style aircraft carrier, HMS Ark Royal, was built there before its launch in 1914.

"The history of the harbour is a source of great pride for everyone working here," said the Catapult's Dave Hailes, who is managing the project. "It's a constant source of inspiration to hear some of the stories from its past. This extensive refurbishment will mean we can continue to be at the forefront of innovation for years to come."

Latest news and developments

£920k boost for Scottish offshore wind R&D

Backed by the Scottish Government, we have announced a £920,000 programme, based around our world-leading Levenmouth Demonstration Turbine, that aims to advance offshore wind research in Scotland.

Already a demonstration hub for innovative technology companies across the UK, the funding will increase access to the 7MW turbine for businesses, enabling them to take advantage of our technical expertise and our industry and academic partnerships. It will also fund the establishment of a lidar test facility and facilitate the creation of a "virtual wind farm."

"This investment is another demonstration of the Scottish Government's long-standing commitment to maximising the huge potential of offshore wind as a sustainable energy source," said Paul Wheelhouse, Scottish Government Minister for Business, Innovation and Energy. "It's becoming increasingly clear that offshore wind is integral to Scotland's sustainable energy future – as well as helping us to achieve our ambitious climate change targets."

Immersive Hybrid Reality laboratory unveiled at Fife College

A world-leading Immersive Hybrid Reality (iHR) laboratory, which provides ultra-realistic training environments for offshore wind turbine technicians, was recently unveiled at the Rosyth Campus of Fife College by Scottish Government Minister for Further Education, Higher Education and Science, Shirley-Anne Somerville MSP.

The enhanced virtual reality system allows students to conduct detailed fault-finding inspections of the top of a virtual 7MW offshore wind turbine, based on our Levenmouth Demonstration Turbine.

The unique hybrid element combines the real and virtual worlds, allowing users to see their own hands and feet, real tools or manuals, whilst seemingly at the top of the turbine, over 110m above the waves. The iHR system has been developed by the Energy Skills Partnership, Heriot-Watt University and Animmersion UK in partnership with the Catapult. The first phase has created a top-of-turbine inspection, with phase two to develop an inspection of the inside working of the turbine now underway.

Catapult and SPR sign collaboration agreement

A deal between ScottishPower Renewables (SPR) and the Catapult will see the organisations working together to develop projects to tackle the key technology challenges facing offshore wind.

The collaboration agreement will prioritise SPR's innovation needs for its portfolio of offshore wind projects and identify the high-growth UK companies with the potential solutions to address these challenges.

The first collaborative project will be a foundation fabrication feasibility study, which will aim to review opportunities for efficiencies in foundation fabrication and help UK companies gain a competitive edge.

"This type of collaborative working agreement is an excellent example of how ORE Catapult can help offshore wind farm owner/operators engage with the UK supply chain to drive forward the resolution of key industry technology priorities, and create UK economic benefit," said Chris Hill, the Catapult's Operational Performance Director. "We hope this partnership will form a blueprint for future, similar collaborative agreements with industry."

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