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ISSUE 9 | WINTER 2016/2017

TECHNOLOGIES OF THE FUTURE

FEATURES

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Innovate UK

ADVANCING WIND, WAVE AND TIDAL ENERGY

We operate the largest concentration of offshore renewable energy technology test and demonstration facilities in support of UK innovation.

Our facilities, along with our highly experienced multi-disciplinary team of experts and engineers, help to prove and de-risk new technologies and bring them to market.

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WELCOME

GUEST FOREWORD - NIALL STUART, CHIEF EXECUTIVE OF SCOTTISH RENEWABLES AHEAD OF THE OFFSHORE WIND CONFERENCE 2017

Niall Stuart
Chief Executive of Scottish Renewables

Despite the many twists and turns in the debate on our future energy system, the ultimate goals have remained surprisingly constant.

While the emphasis may have ebbed and flowed, the objectives of decarbonisation, lowering cost, increasing security and delivering economic benefits have always been the priorities.

It is clear that innovation will play a central role in delivering all four of these objectives.

Incredible progress has been made, and we are now on track for some 10GW of offshore wind by 2020 - but there is so much further to go.

We need to continue the deployment of turbines of ever greater scale, find ever greater efficiencies, and look at new ways to mesh together the wider energy system – onshore and offshore – if we are to answer the difficult questions that lie ahead.

And we need to plot a clear continuum of support for tidal technology if it is to reach commercial scale and compete with other, less established, forms of low carbon power.

The Catapult is playing a vital role in all these areas, and offshore wind is rapidly becoming a fantastic case study of the benefits that innovation can deliver when we create the conditions for business, government and the research community to really focus and work together on a shared endeavour.

We look forward to continuing our work together at this year's Scottish Renewables' Offshore Wind Conference as we meet to debate and discuss the key challenges that lie ahead.

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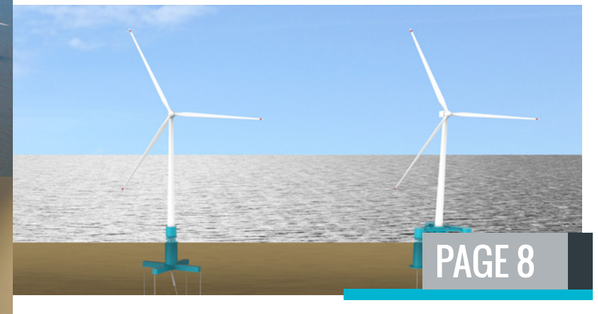


WORKING WITH INNOVATIVE UK SMES

ACT Blade Ltd

We're working with Edinburgh-based SME ACT Blade to develop and test next-generation engineered textile wind turbine blades.

After they responded to one of our Innovation Challenges, our Strategy & Commercialisation team worked with engineers from world-leading yachting design specialists SMAR Azure, resulting in the spin-off company ACT Blade. The aim was to study the feasibility of adapting their sail modelling technology into modular blades that are over 50% lighter than those in use today.

Put simply, a lighter blade can achieve greater power production. If a blade is lighter, it can be made longer than the current 55m standard. In turn, the longer blade captures more wind. That increases energy production, which lowers the levelised cost of energy (LCoE).

Made up of an internal composite structure and high-tech textiles, as opposed to the prevailing fibreglass, ACT Blade's disruptive design has the potential to reduce the LCoE by 8.7% while increasing energy production by 9.7%.

The development of modular blades also has implications for developing countries, where poorer infrastructure means full-length blades are all but impossible to transport. And there are environmental advantages, too: while glass fibre blades are landfilled at the end of their working life, ACT Blades will use recycled carbon fibre.

After helping the company to secure several rounds of investment, we're developing a new test rig at our facility in Blyth, which will validate and demonstrate a section of the blade. We're proud to be playing a major role in helping this fledgling Scottish company to develop, and confident that when brought to market, its technology can have a huge impact on the cost of offshore wind.

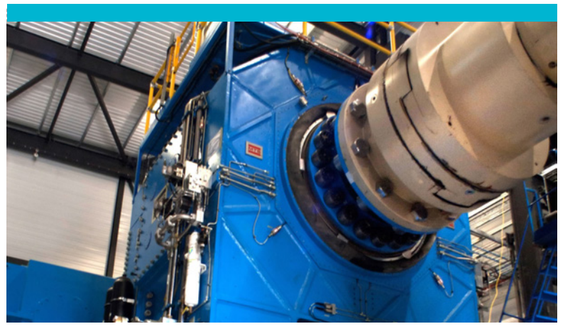
Limpet Technology

For companies developing cutting-edge technologies in the renewables industry, the 7MW Levenmouth Demonstration Turbine is a stage unique in its scale and position. It's the world's largest open-access offshore wind turbine dedicated to research, and the only facility of its kind in the UK. It allows firms like the Edinburgh-based SME Limpet Technology to display its award-winning height safety solutions in action in a real-world setting.

That makes it a more convenient shop window for investors, partners and customers, who might not have the sea survival training needed to go offshore. Film crews, too. "We shot a short film with ITN Productions about our new offshore personnel transfer system on location at Levenmouth," says Philip Taylor, Limpet's Business Development Director. "There's no way that could have happened without ORE Catapult and this unique facility.

"Being able to test equipment on a full-scale, energy-generating offshore wind turbine – that can be accessed simply by walking across a ramp from the shore and is within an hours' drive from Edinburgh airport – is of huge significance in terms of reducing the cost and time to bring new systems to market."

For technology SMEs, testing, demonstrating and proving a new product at work in its operational environment is paramount. Being able to do it in front of potential customers and investors? Well, that could be priceless.

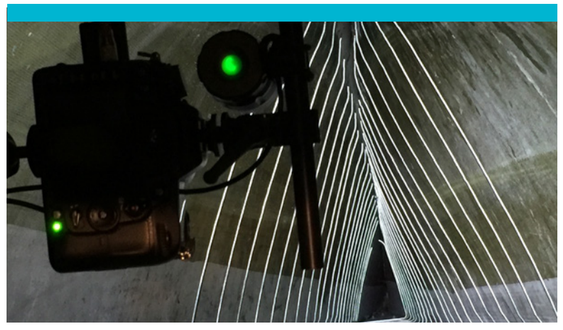


GreenSpur Renewables

Divesting from turbine generators that use Neodymium Iron Boron (NdFeB) magnets (also known as rare-earth magnets) sounds, at the moment, like a pipe dream for the wind industry.

But Essex-based SME GreenSpur Renewables is a company with big ambitions, and they're focused on developing a new Direct-Drive Permanent Magnet Generator (DD PMG) that doesn't rely on rare-earth magnets. The issues with these magnets are many: besides relying on scarce and expensive metals that are almost exclusively mined in China, they are vulnerable to corrosion in sea water atmospheres, and there are practical issues around their assembly. GreenSpur estimates that a magnet switch could cut DD PMG cost substantially. Although rare earth magnets are three times more powerful than their ferrite counterparts, they are 30 times the price by weight of commonly-available ferrites, so magnet costs could be reduced to one tenth of current levels.

ORE Catapult's Strategy & Commercialisation team helped GreenSpur obtain an initial funding call to scale up their pioneering generator into a small-scale 50kW test unit. Our commercial experts also helped them develop their pitch to secure £1.25m of grant funding from InnovateUK, which will be used to move the technology towards a fully-optimised 1MW unit. When scaled up to multi-MW levels, the cost savings could be even greater. Viewed in that context – and with the additional environmental and practical advantages of using ferrite magnets – the attraction is clear.



WideBlue

We're working with optics experts Wideblue – formerly Polaroid's R&D lab – to develop their optical technology into a sophisticated system of lasers and sensors that can detect blade deformation.

The BOHEM (Blade Optical Health Monitoring) project will develop a low-cost, optimised, optical condition monitoring solution for blades that can be used during the development of new designs, and in the operational field.

During the first phase of the 12-month project, Wideblue's sensing technology will be applied to our research blade to learn more about its capabilities. It'll then be deployed on the Levenmouth Demonstration Turbine, where it will undergo trials in a real-world, operational offshore environment. The data generated will be used to monitor individual blade health, allow early detection of any changes in performance, instruct more effective maintenance and allow for better justification of life extensions.

"This is an important project because Wideblue are an innovative UK SME with huge potential," says David Woodhead, a Project Manager in our Innovation & Engineering Projects team. "We're helping them to diversify into an offshore environment, and giving them access to Blyth and Levenmouth to demonstrate their technology. It's a big step forward from the existing technology in this field, and it's a great example of how SMEs can broaden their horizons by moving into the offshore arena."

UK OFFSHORE WIND LCOE BELOW £100/MWH FOUR YEARS EARLY

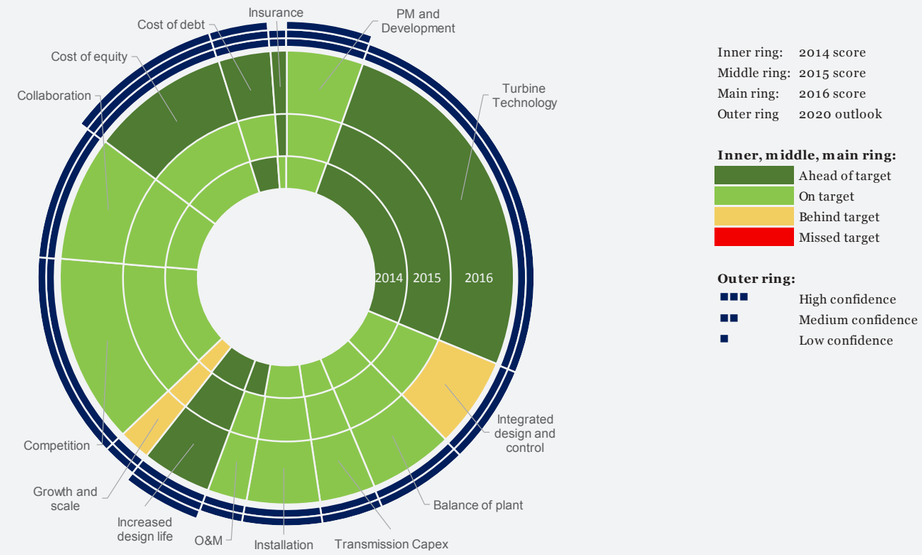
AS OFFSHORE WIND ENERGY COST REDUCTION CONTINUES APACE, THE INDUSTRY IS SETTING ITS SIGHTS ON FURTHER REDUCTIONS, ECONOMIC GROWTH AND JOB CREATION

The third annual Cost Reduction Monitoring Framework (CRMF) report, delivered by ORE Catapult on behalf of the Offshore Wind Programme Board (OWPB), shows that UK offshore wind projects that made a Final Investment Decision (FID) in 2015/16 achieved an average Levelised Cost of Energy (LCOE) of £97/MWh. This is now below the joint UK Government and industry target of £100/MWh by 2020, and has been achieved four years ahead of schedule.

The cost of energy from offshore wind has fallen by 32% in five years due to faster than anticipated deployment of larger turbines, increased competition and lower cost of capital as the risk profile of the sector improves. And there is a high confidence across industry that further significant cost reductions can be delivered from technology innovation and continued collaboration across the sector.

The key findings of the report are:

- Technology developments have made the largest contribution to cost reduction
- Competition at developer level has driven down costs in the supply chain
- Risk profile and the cost of capital is reducing as confidence in the sector develops
- The level of UK content in projects is an increasingly important consideration for developers



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Graphical representation of the CRMF

image left
The London Array

As well as continued cost reduction, the industry is now focusing on increasing UK content and job creation through a more coordinated approach to industrial strategy.

The CRMF report makes a number of recommendations to the OWPB to ensure that the sector continues to build on the great strides already made in reducing costs, including:

- Ensure further cost reduction beyond 2020 and maximise UK benefit through an agreed set of cost reduction priorities, timescales and monitoring process for collaborative actions across the sector.
- Work with government to encourage and support investment in the UK supply chain. This should be built on a coordinated approach to industrial strategy, maximising the supply chain synergies between fabrication, assembly, port infrastructure and operations and maintenance.
- Identify and exploit opportunities to reduce development, consenting and deployment risk in the UK. Consider improved coordination of government policy implementation (energy and environment) and review successful policy and regulation from other European markets that could enhance the UK framework.
- Continue to work with government via the Offshore Wind Industry Council (OWIC) on plans for further Contracts for Difference (CfD) auction rounds and longer-term visibility of the market that would enable it to achieve its maximum potential.

All in all, 2016 has proved a significant year for the industry. 7MW and 8MW turbines have become standard for new projects and the announcement of the second CfD auction round has helped to provide visibility for the sector.

BUILDING THE FOUNDATIONS OF THE FUTURE

AS WIND FARMS MOVE INTO DEEPER WATER, AND DEVELOPERS ARE ABLE TO HARNESS PREVIOUSLY INACCESSIBLE WIND RESOURCES, THE NEED FOR NEW, INNOVATIVE TURBINE FOUNDATIONS IS MORE IMPORTANT THAN EVER TO HELP EXPLOIT THESE NEW OPPORTUNITIES.

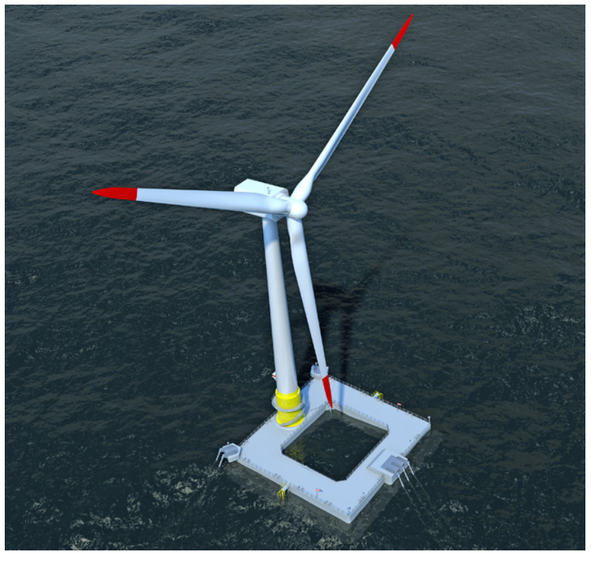
In 1991, the world's first offshore wind farm was built in 2 to 4 metres water depth off the coast of Denmark. The first wind farms saw onshore technologies being adapted for the marine environment, with location driven more by the accessible water depth rather than the strength of the offshore wind resources.

By 2007, technological advances and targeted funding for demonstrator projects such as the Beatrice Offshore Wind Farm were driving the sector forward, with offshore wind farms being built in depths up to 45 metres. Today, wind farm developers are looking into deeper water to further exploit global offshore wind resources. Traditional wind farm foundations and substructures, and their associated deployment methods, must therefore evolve to meet the challenges of anchoring larger turbines in more challenging seabed conditions. The variety of foundation concepts deployed internationally and being developed to date– from monopiles to gravity bases, tripods to jackets, and even floating foundations – makes this an active area of research and development for ORE Catapult.

We're delivering a number of national and international projects across industry and academia, bringing strong engineering expertise to innovations within existing foundation concepts and around novel foundation designs, condition monitoring assessment and corrosion management.

Lifes50+, an international collaborative project involving 12 partners from eight countries, is leading much of the research into floating wind. The project is taking four initial floating concepts - semi-submersible steel and concrete designs, a concrete barge and tension-leg platform - and working through rigorous design and testing procedures. Initially proving and testing the concepts with 5MW turbines, Lifes50+ is now upscaling the turbines to 10MW, to be usable in depths of more than 50m.

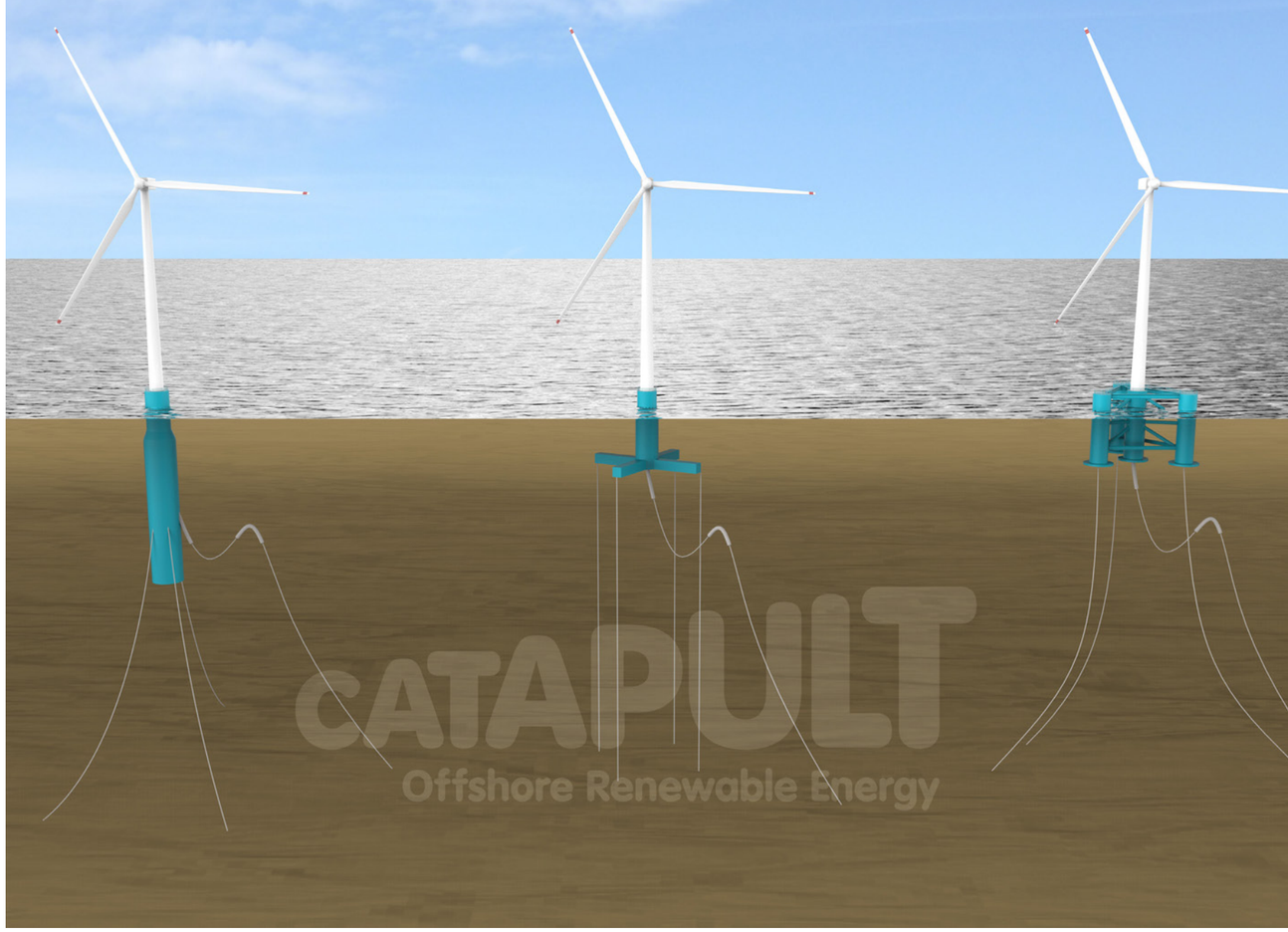
Meanwhile, companies such as Statoil have led the development of deep water solutions. Whilst currently using monopiles, they are planning for the opportunities of the future with floating foundations. Plans are moving forward for commissioning the Hywind demonstrator array



in 2017, with five turbines set to be installed off the coast of Peterhead in Scotland's north east in waters deeper than 100m. This demonstrator has the potential to open the door to a host of sites previously deemed inaccessible.

The potential of gravity-based foundations has been identified by the sector as having the potential to unlock previously inaccessible sites, but has been held back by the need for expensive installation or heavy lift vessels. However, the Demowind project FSFound is providing a solution to this.

EDF Energy Renewables' development of the Blyth offshore wind farm will showcase some of the latest generation offshore wind technologies, including new concrete gravity base foundations, the first of their kind to be built in the world, and installed using a new method of 'float and submerge'. We



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Digital representation of floating foundations

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Ideol floating foundation

are partnering with EDF ER and Royal BAM Group on the FS Found project, aimed at demonstrating and validating float and submerge gravity base foundations (FS GBF) at the design, manufacture and installation stages, moving them from Technology Readiness Level (TRL) 6 to 7.

We're also using our own Levenmouth Demonstration Turbine to better understand load cases on foundations in a real-world environment. Our 'Clone of the Levenmouth Offshore Wind Turbine' (CLOWT) project will see sensors installed on the turbine's blades, tower and substructure, including its foundations, and we'll use the outputs to validate the current design methodologies and tools available for building large-scale offshore wind turbines, reducing design inefficiencies and flaws.

Many of these innovative foundation concepts are on the brink of moving from demonstrator projects to commercial viability, and we can now glimpse the horizon point of affordable and abundant offshore wind energy. The purpose of innovation is to prove concepts, to stretch the art of the possible, and to enable greater technological penetration. Therefore it's vital that funding into research and development continues to maintain the pace of progress and to drive the development of a mature, competitive offshore wind industry.

If you are interested in finding out more about our work in offshore wind foundations and substructures, please contact: Cian.Conroy@ore.catapult.org.uk

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Drone at the Levenmouth Demonstration Turbine

THE RISE OF THE DRONES

EXPLOITING INNOVATIVE NEW TECHNOLOGIES TO DRIVE DOWN OFFSHORE WIND COSTS

The fields around the historic city of Cambridge are alive with the buzz of drones. Since the UK's Civil Aviation Authority (CAA) relaxed its restrictions around unmanned aerial vehicles (UAVs) in summer 2016, the online retailer Amazon has been testing its pioneering delivery drones there. In December, the first package arrived via autonomous drone: a giant leap forward for the technology and its commercial applications.

Shopping isn't the only industry where remotely-operated aerial vehicles are being trialled. Alongside the UK SMEs Cyberhawk and W3G Marine, ORE Catapult is working to develop pioneering drone technologies that could significantly reduce the cost of offshore turbine inspections when compared to traditional methods.

"In offshore renewables, the operations and maintenance phase of a project involves many tasks that could be automated with the use of drones," says Andy Kay, ORE Catapult's Innovation Manager. "Turbine blade inspections are just one of them.

"Here at the Catapult, we undertook a review of the offshore wind industry's challenges and requirements in the area of drone-based turbine inspections, with the aim of understanding how we can support their wider exploitation.

"We spoke to wind farm operators, inspection companies and turbine manufacturers as part of a wide-ranging consultation, and found that one of the main barriers to the wider adoption of drone technology is the lack of open-access turbine availability."

The result was the development of the Remote Inspection Technology Evaluation service, or RITE. The Catapult utilises the Levenmouth Demonstration Turbine to help innovative small enterprises improve and commercialise their drone sensor technologies by testing in a safe environment. "It helps them gain credibility and build evidence that they can take to potential clients," says Kay.

"The other main challenge is facilitating the automation of the drones," says Kay. "The ultimate endgame for these technologies is that they become fully autonomous, with pre-planned, controlled flightpaths. At the moment, they're controlled by remote control – but that still requires a highly-skilled operator gaining access to the site. If they're controlling it from a boat, there are issues around movement, and seasickness... there's still a lot of work to be done on that front."

The days of fully-automated turbine blade inspections are not upon us yet, but for now the technology presents a world of possibility. And, as ever, ORE Catapult's expertise is at the forefront, helping it take flight.

GRID INTEGRATION CHALLENGES FOR OFFSHORE WIND

Simon Hogg
DONG Chair in Renewable Energy
Durham University

AHEAD OF PRESENTING AT THE SCOTTISH RENEWABLES OFFSHORE WIND 2017 CONFERENCE, PROFESSOR SIMON HOGG, DONG CHAIR IN RENEWABLE ENERGY AT DURHAM UNIVERSITY, HIGHLIGHTS SOME OF THE KEY CHALLENGES IN GRID INTEGRATION FOR OFFSHORE WIND.

As electricity generated from offshore wind becomes an ever increasing part of our energy mix, the ways in which we deal with its intermittency of supply, and how we integrate it into our existing energy grid networks, are becoming more important than ever.

The biggest grid integration challenge we face in offshore wind today is the lack of availability of suitable energy storage. While most of the funding in new technologies has been focused principally on batteries, it is the potential for storage on a larger scale – and the base technology supporting it – that must receive more focus.

There just hasn't been the investment in large-scale energy storage necessary to mitigate intermittency and optimise output, which will drive efficiency and lower costs. With a lack of suitable storage on the network, demand management is going to have to work much harder. Therefore, we need to adopt a more holistic approach to energy storage.

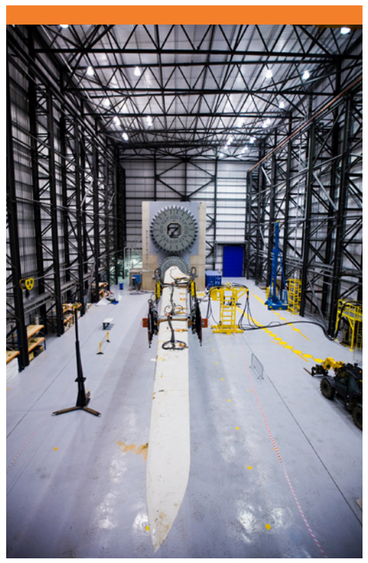
This approach has proved difficult, though: mainly because of the wind industry's growth, which has been much faster than many people predicted. In 1991, turbines were 450kW in size. By 2016 we saw the first 8MW turbine built, demonstrated, and on the market.

As turbine timescales have accelerated beyond what was initially envisaged, to some extent energy storage has been a victim of the wind industry's success. If the industry had predicted we would be where we are now in terms of generating capacity, then perhaps there would have been more of a focus on large-scale storage over the last decade.

Looking ahead, if we are to make the most of the opportunities available in the next phase of the development of our energy system, we must get better at storage. The technologies are available: compressed air energy storage, for example, which has so far only been trialled outside of the UK. This could be exploited in the UK to improve the match between our energy system and our future needs.

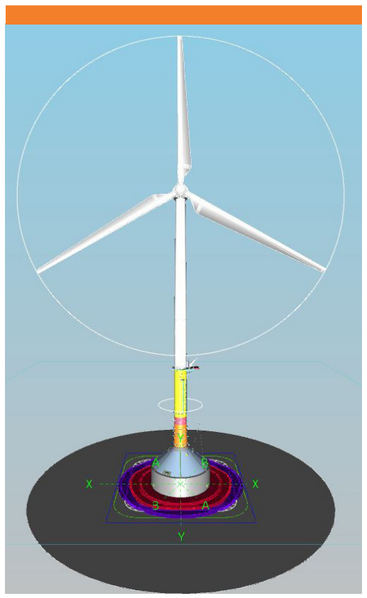
The good news is that while we face many challenges in overcoming offshore wind's grid integration issues, none of them are insurmountable.

PROJECT SNAPSHOTS



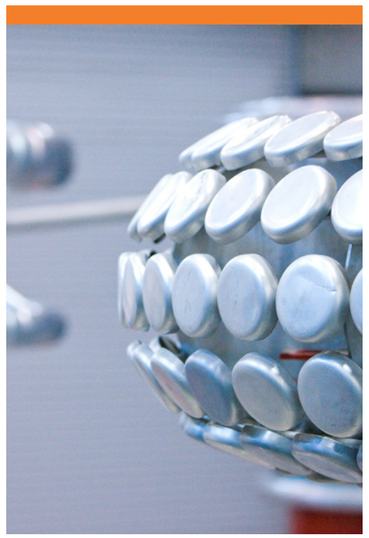
XL Blade

XL Blade's overarching objective is to reduce the overall cost of offshore wind by designing, validating and deploying the world's largest offshore wind turbine blade. The project combines the technological leadership of three offshore wind industry leaders - Adwen, LM Wind Power and ORE Catapult - across three participating countries. At 88 metres long, the blade will achieve a significant reduction in the Levelised Cost of Energy (LCoE) by means of lighter construction and a more predictable operational expenditure (OPEX) through reliability-driven design. ORE Catapult will test the blade in our world-leading 100m facility, as well as continuing our work on the issue of blade leading edge erosion.



FSFOUND

The FSFOUND project will demonstrate and validate float-and-submerge gravity based foundations (GBF) that have the potential to impact positively upon the development of deep-water offshore wind farms (>35 metres) and lower the cost of offshore wind energy. FSFOUND will demonstrate the feasibility of GBFs, which will be used during the installation of the Blyth Offshore Wind Farm in 2017, at all critical project stages. ORE Catapult is designing and commissioning a sensor system for the GBFs. By synchronising these data with the turbine and ORE Catapult's met mast data, we plan to analyse the performance of the foundations in the challenging conditions they are exposed to.



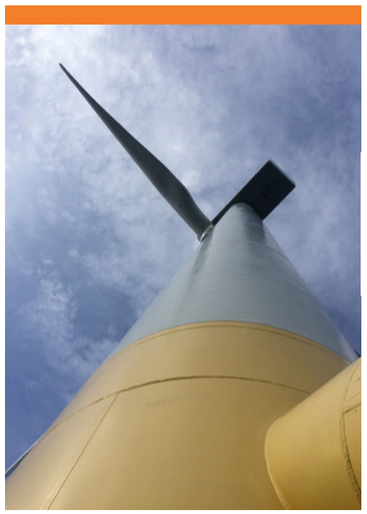
CHEG

CHEG (Compact High Efficiency Generator) is a project to advance state-of-the-art wind turbine generator technology by reducing the size and increasing the efficiency of the generator, ultimately reducing the cost of energy. CHEG will deliver a pseudo direct drive (PDD) machine based around the innovative magnetic gear technology of Sheffield-based engineering firm Magnomatics. ORE Catapult will test a prototype design using its 3MW drive train test facility. Preliminary overall cost of energy modelling shows significant advantages from the PDD system when compared to other current machine topologies, with notable increases in efficiency.

Knowledge | Collaboration | Innovation

MaRINET 2

MaRINET 2 follows on from the successful first phase of the Marine Renewables Infrastructure Network (MaRINET), which provided periods of 'free-of-charge' access to world-class R&D facilities for marine renewable energy technologies. With secured funding from the recent Horizon 2020 - INFRAIA call, the 39 project partners from across Europe will continue to accelerate the development and testing of offshore renewable energy systems, providing access to around 57 research and testing facilities. ORE Catapult will again participate in the project, hosting European partners and providing its world-leading capabilities to all interested applicants that successfuly access the available funding.



CLOWT

We're opening up our unique Levenmouth Demonstration Turbine to SMEs in the sensors sector to create a "digital clone" of the turbine. The CLOWT (Clone of the Levenmouth Offshore Wind Turbine) project will advance the industry's understanding of how large-megawatt turbines behave under the strains of real-world operation, using data gathered from innovative sensor instrumentation. By building up a clearer picture of how the enormous offshore turbine reacts to the conditions, loads and forces it experiences, we can identify opportunities for cost reduction through design optimisation. One of the project's first outputs is expected to be the "Experimental Verification of Aeroelastic Models," produced in collaboration with the University of Strathclyde, which will verify the accuracy of existing industry design tools and reduce their associated modelling uncertainty.

RiaSoR

The Reliability in a Sea of Risk (RiaSoR) project has three objectives: establish industry best practice in reliability testing for wave and tidal devices through improved load measurements and verification; standardise design guidelines for marine energy systems; and increase safety in marine energy operations. ORE Catapult will model systems and develop enhanced condition monitoring methodologies to improve the reliability and availability of electrical power conversion. The goal is to consistently learn from the physical interactions between the device and its environment, while embedding this understanding, and building robustness, into marine energy technology designs.

NEWS ROUND UP

World-first tech test opportunity for sensor SMEs

SMEs in the sensor sector have a world-first opportunity to prove and commercialise their technology on our Levenmouth Demonstration Turbine.

In a programme co-funded with the Scottish Government, we're developing a digital Clone of the Levenmouth Offshore Wind Turbine (CLOWT) to monitor its behaviour in real-world conditions. In parallel, a number of SMEs will have the chance to demonstrate their innovative sensor technology alongside existing best-in-class products.

A workshop in Leven on 12th January provided potential participants with more details about the competition and an opportunity to discuss the turbine and the Catapult's role in commercialising their technology. Highlights from the session are available to those who couldn't make it on the ORE Catapult website.

Catapult community collaboration scoops Green Energy Award

Our Levenmouth Demonstration Turbine scooped the Best Community Engagement Award at the 2016 Scottish Green Energy Awards in Edinburgh.

The Catapult has worked extensively with local partners, including Fife Council and Levenmouth Academy, to develop education and training programmes that deliver in-demand skills to local people. Our engineers have mentored pupils at a local primary school, and apprentices and lecturers from Fife College's Turbine Technician course have been given the chance to inspect an offshore turbine for the first time.

The Catapult was shortlisted in two different categories, with Peter Greaves, our Research Structural Engineer in blades, nominated for the Rising Star Award.

Wind energy benefitting from collaborative research, says IEA Wind

Wind-generated electricity met close to four percent of the world's electricity demand in 2015 – a record-setting year with more than 63GW of new wind power capacity installed globally, according to IEA Wind's latest annual report.

Worldwide capacity stood at about 433GW of wind power and more than 85% resides in the countries represented in the International Energy Agency Wind (IEA Wind) Technology Collaboration Programme (TCP).

In the UK, offshore capacity increased to over 5GW and is expected to reach 10GW by 2020. The UK generates more electricity from offshore wind than any other country in the world, meeting around 5% of annual UK electricity requirements.

The full report is available for download at www.ieawind.org.

Latest news and developments

SALE on at Levenmouth turbine

The Levenmouth Demonstration Turbine will also play a pivotal role in validating software developed by Ocean Array Systems (OAS) to improve the control strategies of offshore turbines.

Improved turbine control, adopted farm-wide, could see as much as a 2.4% reduction in the Levelised Cost of Energy (LCoE) of offshore wind.

The Innovate UK-funded project, Simulation to enable Asset Life Extension of wind turbines (SALE), will use production and load sensor data from the turbine, combined with wind conditions data collected from a met mast and a lidar unit located at the site. These will then be compared with the numerical model of the wind conditions and turbine response of OAS' TurbineGRID software to validate the tool.

Catapult gains IIP accreditation

We had cause for celebration in October after achieving the internationally-recognised Investors in People accreditation – the defining standard for people management.

The standard provides straightforward, proven frameworks for delivering business improvement through people and the Catapult is now accredited through to 2019 after demonstrating commitment to its staff across a range of key indicators.

"To be celebrating accreditation only two and a half years after the merger of ORE Catapult with Narec is a fantastic achievement and underlines our ongoing commitment to people development, engagement and communication and to providing an excellent service for our customers," said Andrew Jamieson, ORE Catapult Chief Executive.

Knowledge partnership gives Scottish SMEs world-class wind opportunity

Scottish SMEs have an 'enormous opportunity' to develop wind farm technology and exploit global markets thanks to a new programme giving access to the country's leading researchers and testing facilities.

The Energy Technology Partnership (ETP) is an alliance of 12 Scottish universities offering world-class capability and resources in energy technology development. Scottish SMEs and SMEs interested in establishing a base in Scotland can access a pool of around 250 academics and 700 researchers to explore market opportunities and technology ideas.

The fund also offers the opportunity to access £250million of University research facilities for testing prototype technologies – providing the spark needed to get new ideas to the marketplace. Up to £20,000 in funding is available to cover the cost of this stage of the process.

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