



THE UNIVERSITY of EDINBURGH
School of Engineering

POLICY AND
INNOVATION GROUP
**UK OCEAN ENERGY
REVIEW**

2023



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Offshore
Renewable
Energy

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Policy and Innovation Group

The Policy and Innovation Group is part of the Institute for Energy Systems (IES), which is one of the seven research institutes within the School of Engineering at the University of Edinburgh. The Policy and Innovation Group combines expertise in offshore energy technology, energy system organisations and institutions, and the wider policy and regulatory landscape. They apply a range of quantitative and qualitative research tools and methods including energy system modelling, future transition scenarios, techno-economic analysis and innovation pathways. This leads to the development of policy guidance reports, energy system roadmaps and economic and energy system analysis for technology developers, public and private investment and government departments.

Find out more about the Policy and Innovation Group at <http://www.policyandinnovationedinburgh.org>

Supergen ORE

The Supergen programme was set up in 2001 by the Engineering and Physical Sciences Research Council (EPSRC) to deliver sustained and coordinated research on sustainable power generation and supply. For phase four of the programme, the Supergen Wind and Supergen Marine Hubs were combined into the Offshore Renewable Energy Hub. The Supergen Offshore Renewable Energy (ORE) Hub builds on the work of the former Hubs, and looks at synergies between offshore wind, wave and tidal technologies as well as building on current research in each area. Led by the University of Plymouth, Supergen ORE provides research leadership to connect stakeholders, inspire innovation and maximise societal value in offshore renewable energy.

Find out more about Supergen ORE at <https://supergen-ore.net/>

Wave Energy Scotland

Wave Energy Scotland (WES) is driving the search for innovative solutions to the technical challenges facing the wave energy sector. Through a competitive procurement programme, they support a range of projects focused on the key systems and sub-systems of Wave Energy Converters. The aim is to produce reliable technology which will result in cost effective wave energy generation. WES was formed in 2014 at the request of the Scottish Government and is a subsidiary of Highlands and Islands Enterprise. The aim of WES is to ensure that Scotland maintains a leading role in the development of marine energy.

Find out more about Wave Energy Scotland at <https://www.waveenergyscotland.co.uk/>

Marine Energy Council

The MEC is the trade association and representative body for the UK's tidal stream and wave energy industries. Established in 2018 the MEC is committed to realising the potential of tidal stream and wave energy, to support a secure, cost-effective transition to net zero, and make the UK attractive to renewable investors. The MEC has played a key role in influencing the external policy environment, whilst proactively defending the interests of tidal stream and wave energy. This includes securing the ringfence for tidal stream in the UK's last renewable auction, identifying and improving investment and R&D opportunities, and working collaboratively with key stakeholders to maintain the UK's leadership in ocean energy.

Find out more about the Marine Energy Council at <https://www.marineenergycouncil.co.uk/>

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- Marine Energy Council
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Cover Images:

Upper left: Mocean Blue-X deployed off Orkney in their Renewables for Subsea Power project. (Credit: Mocean Energy)
Bottom: Installation of tidal turbines at the MeyGen project (Credit: SIMEC Atlantis Energy)

MINISTERIAL FOREWORD

The Department for Energy Security and Net Zero is leading the UK's efforts to reach Net Zero by 2050, and create a more secure, resilient domestic energy supply to consumers. The transition provides us with many opportunities to shape this country for the better, but creating a system that is both flexible and reliable will be a challenging task. The UK is a global leader in the field of climate change, and we must continue to find and develop more ways to extract naturally occurring energy through renewables. For this reason, the fully predictable generation offered by tidal stream, and the significant potential of wave energy, makes these some of the most promising technologies available today. This report sets out how much potential these technologies have, and the progress made in 2023 to expand these industries so that they can contribute to the UK's energy transition.

Changing Tides

Tidal stream has the potential to make our electricity system more resilient and diverse, while providing sustainable growth opportunities and supporting the delivery of our flagship policies on Levelling Up and the Just Transition. I'm pleased to see that in 2023, significant progress has been made, and the industry is on track to achieve the scale needed this decade.

Thanks to another ringfenced budget for tidal stream, the capacity secured in the Contracts for Difference Allocation Round 5 means that we now expect 100MW to be deployed in UK waters by 2028. This is a fantastic achievement, given that the UK already represents over half the world's installed capacity. This expansion will solidify the UK's position as a global leader on tidal stream.

That expertise was recognised internationally in 2023, evidenced by the European Commission's Horizon Europe Programme selecting two UK tidal stream developers to deliver upcoming projects. Orbital Marine Power and Nova Innovation will lead construction on two €20m multi-turbine projects in UK waters, funded by the UK Government's Financial Guarantee.

We are proud to continue supporting academics who work tirelessly to help our understanding of the role marine energy could play in the future decarbonised energy system. Last year, the Engineering and Physical Sciences Research Council – part of UK Research and Innovation - invested £7 million into the CoTide project, a collaborative undertaking between Oxford, Edinburgh and Strathclyde universities to deliver the next generation of cheap, scalable and reliable tidal stream turbines. This is on top of the £7.5million awarded by the EPSRC to the Supergen Offshore Renewable Energy (ORE) Impact Hub to accelerate the impact of current and future ORE devices and systems.

Riding the wave

Wave energy is another promising technology which could further diversify our energy mix. I'm delighted that Scotland is now one of the key locations for wave energy globally.

In 2023, UK developers successfully secured both public and private funding, milestones that will encourage development of this innovative technology. Mocean was awarded £3.2 million to develop its Blue Horizon 250 kW Wave Energy Converter via EuropeWave, and AWS Ocean Energy have completed at-sea testing of a 16 kW prototype of their Archimedes Waveswing. Both companies are supported by Wave Energy Scotland, which continues to drive innovative solutions to the technical challenges facing the wave energy sector.

A great deal has been achieved this year through the collaboration of government, academia and industry. I am hopeful that in 2024 we will continue to see milestones being achieved in the development of tidal stream and wave energy.

I would like to thank the authors of the report for their work in presenting what a year it has been for the UK marine energy, and to all stakeholders who continue to cooperate with the Government on maximising these opportunities.



Andrew Bowie MP
Minister for Nuclear and Renewable

1 OVERVIEW

At an international level, the demand for a diverse, resilient and, most importantly, Net Zero energy system has never been clearer [1]. As a result, the future role of the UK ocean energy sector, and the policy programmes that will be required to underpin its continued development, are enjoying increasing prominence within the national policy-making landscape [2]. Across the UK, both industry and academia continue to highlight the benefits that a commercially successful ocean energy sector brings and the role that this sector has in helping to address our Net Zero, energy security and just transition commitments [3]. This collaborative approach, combined with the UK's flagship Contracts for Difference (CfD) market support mechanism, has helped to drive the development of one of the world's most successful and mature ocean energy sectors.

Over the course of 2023, the UK has provided continued support to its ocean energy sector by setting a ringfence for the second consecutive time within the CfD mechanism. Contracts have been awarded for nearly 100 MW of tidal stream projects to date, the largest such allocation in the world. Coupled with the sustained support offered to wave energy technology developers via world-leading innovation programmes, ocean energy in the UK is poised to play a substantial role in the national energy mix over the coming decades.

However, at such a critical point, there is a need for increased awareness of the challenges posed by current economic conditions and supply chain insecurities, both of which pose a threat to the continued development of the sector. In addition, despite a growing understanding of the non-price factor benefits that a commercial wave and tidal stream sector can bring to the UK economy, such as regional socio-economic growth and energy system cost savings, there is still a requirement for the sector to continue to innovate as it chases the cost-reductions enjoyed by other sectors.

With the largest pipeline of tidal stream energy projects in the world now on the immediate horizon, the UK has been presented with an opportunity to provide the support and guidance required to ensure that the progress made by the sector over the preceding years is capitalised upon. By combining this support with a collaborative and coordinated policy programme there is an opportunity, in this critical decade for climate action, for the UK to cement its position as the leading nation in both ocean energy development and deployment.

The O2 in operation (Credit: Orbital Marine Power)

Tidal Stream Energy Highlights

2023 has proven to be a pivotal year for the UK tidal stream sector, with many developers launching ambitious projects designed to accelerate commercial array-scale deployments:

- The UK government awarded a record number of Contracts for Difference to the tidal sector, with 11 different contracts granted across the UK at a Strike Price of £₂₀₁₂ 198/MWh;
- Orbital Marine Power have been selected by the European Commission's Horizon Europe Programme to deliver a 9.6 MW tidal stream turbine array project, EURO-TIDES;
- Nova Innovation has also won Horizon Europe funding for a 4 MW tidal stream farm off the coast of Orkney, with the SEASTAR project set to deploy the largest number of turbines in an array anywhere in the world;
- A recent report by the London School of Economics, 'Seizing sustainable growth opportunities from tidal stream energy in the UK' [4], emphasises how tidal stream can deliver sustainable economic growth, enhance net zero efforts, improve energy security and generate jobs across the UK;
- The Scottish government's draft energy strategy released in early 2023, outlines the vast potential of tidal stream technology and plans to consult across government on ambitions for realising its potential.

Wave Energy Highlights

The UK wave energy sector continues to lead on the international stage as multiple technology developers and academic institutions strive to develop the next generation of wave energy converters (WECs):

- Now in its third and final phase of pre-commercial procurement, the innovative R&D programme EuropeWave has progressed CETO Wave Energy Ireland, IDOM Consulting, and Mocean Energy to final design and prototyping, in anticipation of real sea testing;
- Under their Direct Generation Concept Creation Competition, Wave Energy Scotland has awarded five developers funding to develop their design concepts. These are 4c Engineering, AWS Ocean Energy, Southampton and UTC, WaveX, and TTI Renewables;
- Mocean Energy and energy management specialists Verlume, with funding from Wave Energy Scotland, have engaged in a collaborative project to deliver low-carbon power to critical sea-based infrastructure;
- The Scottish Government's draft energy strategy, released in early 2023, recommends continued support for Wave Energy Scotland and will provide £18.25 million of investment to support the long-term development of the sector.

2 SUPPORTING POLICIES FOR OCEAN ENERGY

2.1 NATIONAL STRATEGY

The design and implementation of energy policy within the UK is made more complex by the presence of the devolved administrations in Wales, Scotland, and Northern Ireland, all of whom have differing levels of autonomy and policy decision-making. This is further complicated by the different Net Zero timelines that each ruling party, at devolved and national levels, has adopted.

The research, development and implementation of energy policy at a UK government level is primarily the responsibility of the Department for Energy Security and Net Zero (DESNZ). This new government department, formed in 2023, has taken on the energy policy responsibilities of the former Department for Business, Energy and Industrial Strategy. Historically, wider UK energy policy has aimed to unite the different administrations in a shared ambition to resolve the energy trilemma to decarbonise electricity generation, ensure energy security and minimise the cost of electricity to consumers [5]. However, as low-carbon energy becomes increasingly synonymous with low-cost energy, due to the cost reductions experienced by renewables, this strategy is beginning to evolve.

Within the UK, energy policy is largely devolved to the Northern Ireland Executive, yet it is only partially devolved to the Scottish and Welsh governments, restricting their ability to make decisions and policy independently of UK government. However, the ability to enact policy that is designed to tackle climate change, through policy levers such as the promotion of renewable energy, energy efficiency and electricity generation and transmission development are partially devolved matters, allowing the devolved governments some powers in governing their overall domestic energy mixes.

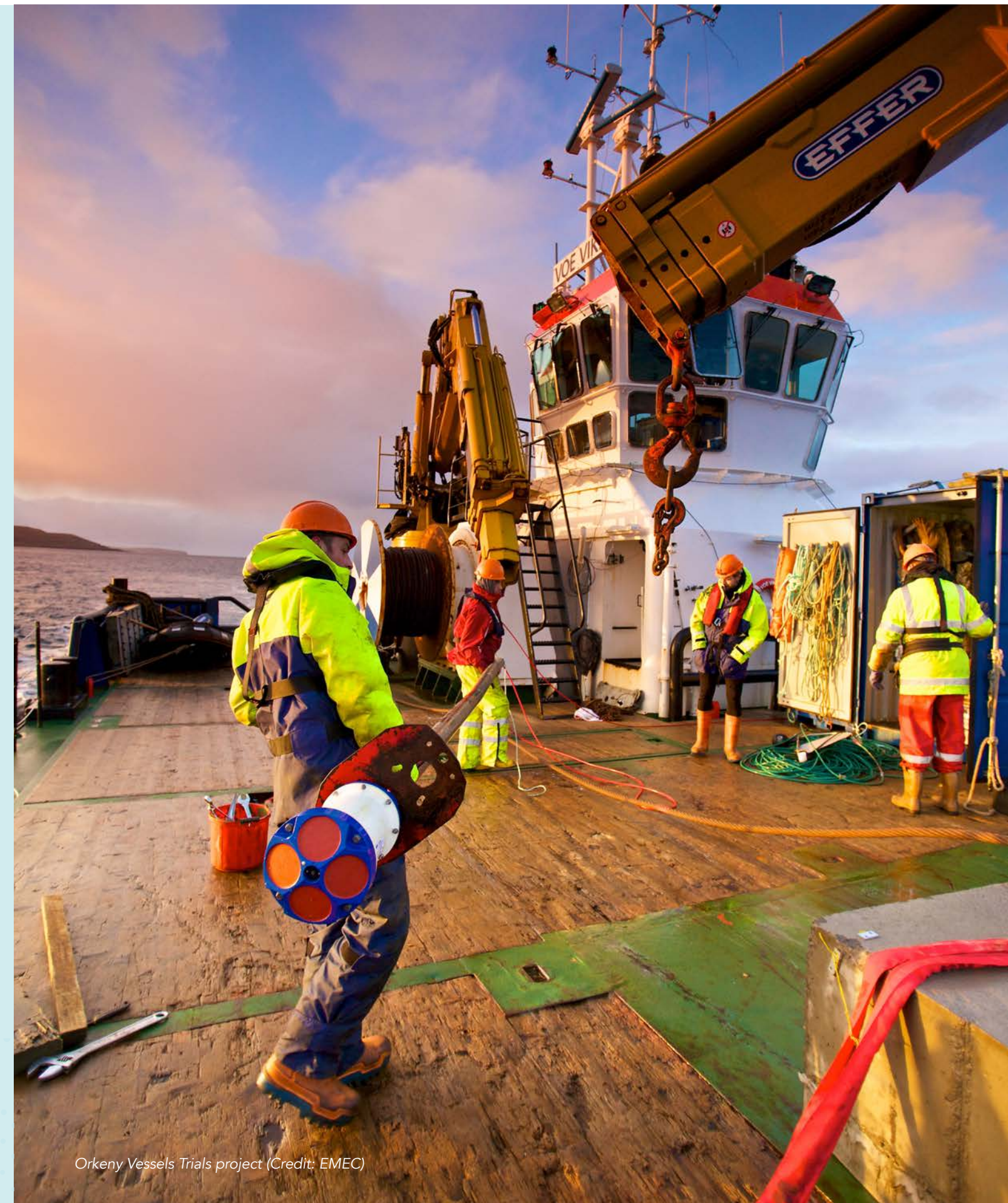
Subsea cables feeding onshore at Fall of Warness test site
(Credit: EMEC)

United Kingdom

For British society, 2023 was a pivotal year for the perception of climate change, as the UK recorded the highest national summer temperature extremes since records began. As the challenges and dangers of a rapidly warming climate become clearer, both nationally and internationally, the UK has a growing role as a world leader in the effort to mitigate the worst extremes of the climate emergency. In response to this challenge, the UK has undertaken a comprehensive effort to rapidly increase the amount of renewable energy sources in its domestic energy mix and has committed to an ambitious and legislatively bound target of achieving Net Zero by 2050 [6]. While a national transition to a Net Zero economy will provide the obvious benefit of low-carbon emissions, it also proves the opportunity for jobs, socio-economic growth and the development of new sustainable industries. However, these benefits are attractive to nations across the globe and the UK currently faces growing competition from the USA and EU, both of whom have committed to large-scale, well-resourced policy programmes to promote the accelerated uptake of renewables into their national energy mixes. With just over a decade remaining for the UK to meet its ambition of a decarbonised electricity system by 2035 [2], the argument for faster progress and continued leadership with regards to sustainable policies is clear.

The role of wind and solar as the foundation of the UK's established Net Zero energy system is clearly defined, with long-term targets set and policy support fixed. However, ensuring that the UK delivers a sustainable, diverse and resilient energy mix, that harnesses all our national resources, will be key to achieving Net Zero in a cost-effective manner. To this end, there is now a growing understanding of the role that our abundant wave and tidal stream resources could play in helping to underpin and strengthen our national energy mix. This growing consensus can be better understood through the high-level policy guidance reports published by the UK government and other organisations over the previous years:

- In 2023, the UK government responded to the Environmental Audit Committee's report 'Accelerating the Transition from Fossil Fuels and Securing Energy Supplies' [7] by underlining their commitment to exploring the potential of tidal power to contribute to our Net Zero ambitions [8]. In the same response they committed to reviewing the merits of setting a potential target for tidal stream deployment;
- The British Energy Security Strategy (BESS), published in 2022, remains the most recent national energy policy report published by the UK government. This report explicitly links a Net Zero energy system, achieved through the increased provision of renewable energy resources, to enhanced levels of energy security. The BESS also highlights the need to 'aggressively explore' tidal energy as a future source of clean energy and the potential importance of funded collaboration with international partners;
- To enable the delivery of the commitments in the BESS, DESNZ has strengthened the National Policy Statement for Renewable Energy Infrastructure, including for the first time a framework for assessing planning applications for tidal stream projects of above 100MW capacity [9]. The draft planning guidance contains provisions for assessing and mitigating impacts of tidal stream infrastructure on seabed habitats and on distributions or movements of marine species;
- The "Net Zero Strategy: Build Back Greener", published in 2021 and updated in April 2022, is the government's primary climate change policy document and aims to keep the UK on track for meeting the UK carbon budgets, the 2030 Nationally Determined Contribution, and net zero by 2050 [11]. This report also acknowledges that the UK possesses some of the best ocean energy resources in the world and highlights the ongoing efforts to explore their role in meeting net zero targets.



Orkeny Vessels Trials project (Credit: EMEC)



Cliffs of Bluemull Sound (Credit: Nova Innovation)

Scotland

Scotland continues to hold the most ambitious climate targets within the UK, with the Scottish Government committed to achieving Net Zero emissions of all greenhouse gases by 2045 [12]. In December 2020, the Scottish Government updated its Climate Change Plan, reflecting the increased ambition of the targets set by the Climate Change (Scotland) Act 2019. Scotland's transition to Net Zero is supported by the Scottish Government's vision for the future of the energy sector and includes a target for the equivalent of 50% of the energy for Scotland's heat, transport and electricity to come from renewable sources by 2030. However, meeting these ambitious targets will not be easy and the Scottish Government will need to continue to proactively shape policy and support rapid renewable energy deployments, wherever possible.

Scotland's geographical location on the western fringes of Europe and its unique geography of seaways and firths, exposes it to a combination of intense winds, Atlantic waves and turbulent tidal currents. As such, the country is well situated to harness its ocean energy potential, should the required infrastructure and financial support be deployed. In early 2023, the Scottish Government published a draft Scottish Energy and Just Transition Plan which presents a vision for Scotland's decarbonised energy system and the collective actions needed to deliver this [13]. It suggests a potential ambition to deliver at least 20 GW of additional low-cost renewable electricity capacity by 2030, which could help to generate the equivalent of around 50% of Scotland's current total energy demand. This initial draft has also been accompanied by a comprehensive public consultation process, inviting communities, workers, citizens and businesses to provide feedback and shape Scotland's energy transition. This has resulted in over 250 responses relating to the need for an ocean energy deployment target and identifying priority actions to sustain the achievements of the sector to date. Scotland has also benefited from the formation of the Offshore Wind Directorate, a government body responsible for the development of policy work related to offshore renewables, marine energy and sectoral marine planning. The Offshore Wind Directorate supports the development of Scotland's supply chain by growing its manufacturing base and attracting inward investment, demonstrating the potential role for marine energy in Scotland's low carbon energy system and managing the environmental impacts of, and risks to, Scotland's journey to Net Zero through offshore renewables.

Over recent years, Scotland's ocean energy sector continues to make substantial progress as wave and tidal stream developers continue the journey towards commercial-scale deployment. The 2023 CfD AR5 was an unparalleled success for the Scottish tidal stream sector, with a record seven new contracts shared amongst three developers, who are now set to deploy in Scottish waters.

the successful auctions from AR4, there is now over 65 MW of tidal stream energy set for deployment by the end of 2028. This represents a significant proportion of the global allocated capacity for tidal stream and reaffirms Scotland's position as one of the leading nations with regards to development and deployment. The Scottish Government, together with industry itself, continues to advocate for long-term certainty for the ocean energy sector through the CfD and will closely monitor developments relating to the sixth allocation round, due to take place in 2024. Not all of Scotland's tidal stream success was linked to the CfD scheme, with Scottish developers Nova Innovation and Orbital Marine Power each securing £20 million worth of Horizon Europe funding for tidal stream arrays off the coast of Orkney, rated at 4 MW and 9.6 MW respectively.

Through the Wave Energy Scotland (WES) programme, the Scottish wave energy sector has continued to benefit from sustained support and guidance. This has resulted in the completion of the demonstration of the AWS Waveswing device in Scottish waters, support to the re-deployment of Mocean's Blue-X device, demonstration of three mechanical and electrical quick connectors and conclusion of the control system development projects. WES also continues to support technologies emerging from the programme towards commercialisation and is delivering the EuropeWave device development programme in partnership with the European Commission, Ente Vasco de la Energía (EVE) and Ocean Energy Europe.

At a national level, Crown Estate Scotland manages property – including buildings, land, coastline and seabed – on behalf of the Scottish people. The Scottish Crown Estate Act 2019 provides a national framework covering a range of matters relating to management of the Scottish Crown Estate [14]. This requires Crown Estate Scotland to manage the assets in a way that is likely to contribute to the promotion of economic development, regeneration, social and environmental wellbeing. Crown Estate Scotland is a public corporation that holds the rights to lease the seabed out to 12 nm for cables, pipelines and aquaculture and the rights to offshore renewable energy and gas storage out to 200 nm. Net revenue generated by Crown Estate Scotland is returned to the Scottish Government and capital is reinvested in the Scottish Crown Estate, with a £103.6 million returned in the 2022/23 financial year to aid in public spending. In the wave and tidal energy space, Crown Estate Scotland continue to offer ad-hoc leasing whereby applicants can apply for seabed rights to develop projects up to 30 MW in capacity. During 2023, Crown Estate Scotland commissioned Offshore Renewable Energy Catapult to conduct an in-depth market engagement survey of wave and tidal energy sectors to provide an insight into current market conditions and the future project pipeline to inform a review of leasing activities going forward.

Wales

2023 has proven to be a historic year for the Welsh ocean energy sector, where, for the first time, the future development and deployment of both wave and tidal stream energy devices can be seen as essential to meeting long-term energy commitments. Following on from its 2019 climate emergency declaration and subsequent commitment to reach Net Zero by 2050, the Welsh Government has also committed to ensuring that 100% of the country's annual electricity consumption is powered by renewable sources [15]. Coupling this ambitious commitment with the Welsh Governments stated desire to support innovation in new renewable energy technologies places ocean energy at the forefront of the energy transition in Wales.

Welsh waters, with some of the highest tidal ranges in the world and a highly energetic Atlantic-facing coastline, are a prime location for the deployment of wave and tidal stream devices, and as such are drawing interest from a range of developers and test-site hosts. This has resulted in multiple milestones, from the official opening of Wales' first tidal stream energy site, Morlais, to successful awarding of over 22 MW of tidal stream capacity between four companies via the CfD scheme. In addition, the Welsh Government published an independent review of the Marine Licencing Process, providing an important opportunity to improve and streamline the consenting process and support the accelerated development of ocean energy in Wales [16]. The Welsh government has consistently stated its commitment to providing strong policy support for the ocean energy sector, with an aim of capturing at least 10% of the potential tidal stream and wave energy off the Welsh coastline by 2025. This has led to an increasing number of technology developers choosing to site their testing and deployment in Welsh waters.

The responsibility for coordinating the research and development of the ocean sector in Wales lies largely with Marine Energy Wales (MEW), the industry-led stakeholder group representing the wave, tidal and floating offshore wind industries. MEW brings together project and technology developers, test centres, wider sectoral alliances, the supply chain, academia, and the public sector to establish Wales as a global leader in sustainable offshore energy generation. The MEW 2023 State of the Sector report clearly highlights how the development of significant infrastructure projects has helped the ocean energy sector to produce record contributions of £103 million to the Welsh economy during the 22/23 financial year [17]. Of this total, £45.1 million was contributed by the tidal stream sector and a further £44.7 million was contributed by the continued expansion of the domestic supply chain. Spending and investment in both these areas was fuelled by the contributions of two key projects – Morlais Tidal Demonstration Zone, the world's largest pre-consented demonstration zone based in North Wales, and the Pembroke Dock Marine project, a development project that has established a world-class centre for marine energy and engineering with easy access to the Celtic Sea. Overall, this represents a sharp increase from the levels of financial investment made during 2022 and brings the total cumulative spending and investment in the Welsh ocean energy sector to £263 million. The MEW report also estimates that the ocean energy sector provides employment to approximately 440 full time employees across areas such as technology development, supply chain and academia.



The Morlais Tidal Energy Zone (Credit: Welsh Government)

2.2 MARKET INCENTIVES

Contracts for Difference

The Contracts for Difference (CfD) scheme is the UK government's flagship program for supporting low-carbon electricity generation. Based on top-up payments between a wholesale market reference price and a strike price, CfDs offer long-term price stabilisation and are awarded via competitive auctions. The CfD scheme incentivises investment in renewable energy by providing developers of renewable energy projects, normally projects with high upfront costs and long lifetimes, protection from volatile wholesale prices. To date, there have been five allocation rounds (AR) which have seen a range of renewable energy technologies bid into competitive auctions for contracts. In both AR4 and AR5, tidal stream has benefitted from a dedicated minimum budget in the auction, where support is ringfenced for tidal stream in the CfD auction round before the competition opens up to other renewable technologies. This has resulted in a record number of contracts being awarded, with six developers across 11 different projects delivering 53 MW of tidal stream capacity [18]:

- MeyGen was awarded 4 contracts totalling 22 MW to further develop their tidal array of the North coast of Scotland;
- Orbital Marine Power was awarded 2 contracts totalling 7.2 MW at EMEC's Fall of Warness site;
- Magallanes Renovables was awarded a further 3 MW at Morlais in Wales, and 1.5 MW at EMEC's Fall of Warness test site;
- Hydrowing was awarded a contract for 10 MW at Morlais, Wales;
- Verdant Isles awarded a contract for 4.9 MW at Morlais, Wales;
- Môr Energy awarded a contract for 4.5 MW at Morlais, Wales.

Building on the 41 MW of tidal stream capacity that was awarded in AR4, there is now a pipeline for 94 MW of tidal stream projects in the UK, all of which are expected to be commissioned by 2028. While wave energy is yet to benefit from the CfD program, developers are increasingly confident that the technology is on the cusp of the levels of technological maturity required to bid for multi-MW contracts. They are also hopeful that a similar ring-fence fund may be established for the wave sector.

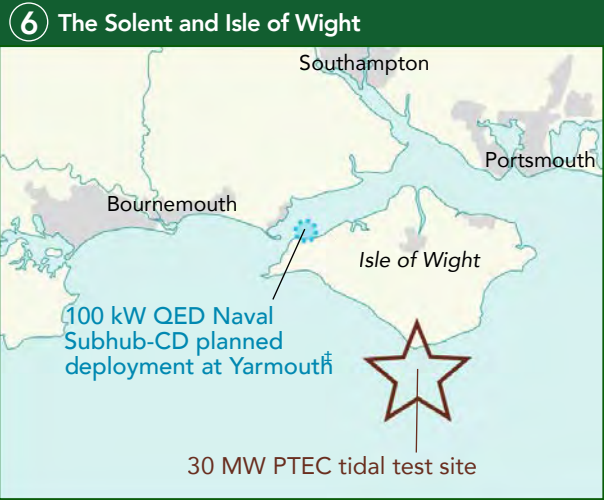
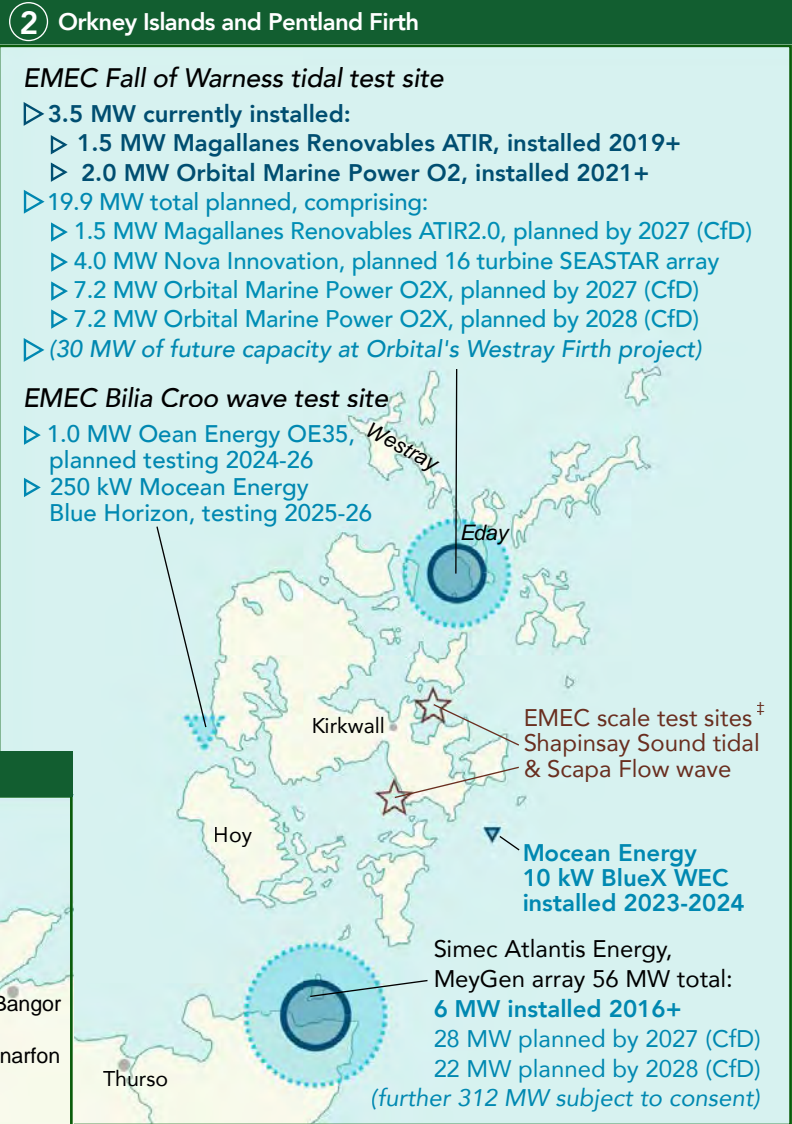
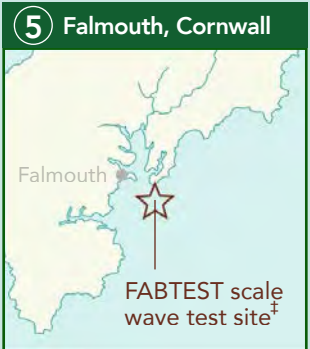
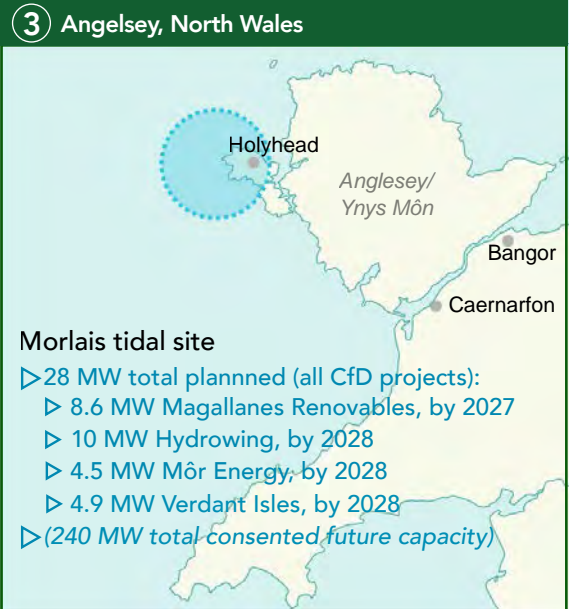
In November 2023, the parameters for AR6 were announced, with significantly increased administrative strike prices for all technologies to address the issues of rising supply chain costs. For tidal stream this is now set at £₂₀₁₂261/MWh. Throughout 2023 the UK government also held consultations on the creation of a Sustainable Industry Reward [19], as a new mechanism to secure broader benefits for UK households and communities from the roll-out of renewable energy technologies.

UK Deployments



Maps show projects currently installed and planned for deployment

- tidal stream
- ▽ wave energy
- ☆ test sites
- ‡ not grid connected



Details correct as of publication, but projects subject to change and some sites may have grid connection constraints. Contains OS data © Crown copyright and database right (2023)

2.3 PUBLIC FUNDING PROGRAMMES



UK Research and Innovation (UKRI)

Launched in April 2018, UK Research and Innovation (UKRI) is a non-departmental public body sponsored by the Department for Science, Innovation and Technology. UKRI is the national funding agency investing in science and research in the UK. Operating across the whole of the UK with a combined budget of more than £6 billion, UKRI brings together the 7 Research Councils, Innovate UK and Research England. The research councils operating within UKRI are Engineering and Physical Sciences Research Council, Arts and Humanities Research Council, Biotechnology and Biological Sciences Research Council, Economic and Social Research Council, Medical Research Council, National Environment Research Council, and the Science and Technology Facilities Council.

<https://www.ukri.org>

The Engineering and Physical Sciences Research Council (EPSRC)

The EPSRC is the main funding body for engineering and physical sciences research in the UK, investing in various fields such as chemistry, energy, engineering, materials and physics. The EPSRC aims to create knowledge and fund innovation with the capability to benefit both society and the economy by supporting research through the provision of fellowships, studentships, research and training grants, competitive funding, and prizes. The EPSRC funds and co-invests with industry, at both national and international levels, helping to deliver advanced research facilities and resources for engineering and physical sciences, including wave test facilities and tidal tank testing. EPSRC also provides technology push policy support mechanisms, such as the Centre for Doctoral Training (CDT), Fellowships, Managed Activity, Standard Grants and Programme Grants. In 2023, EPSRC invested £7 million into the CoTide project, a collaborative undertaking between Oxford, Edinburgh and Strathclyde universities to deliver the next generation of cheap, scalable and reliable tidal stream turbines.

<https://www.ukri.org/councils/epsrc/>



Testing at the COAST Laboratory at the University of Plymouth (Credit: Supergen ORE Hub)



Innovate UK

Part of UK Research and Innovation, Innovate UK is the UK's national innovation agency, providing funding and support to businesses, helping to spur growth via the development and commercialisation of new products, processes, and services. Innovate UK delivers programmes for UK-based companies in all sectors and industries, from pre-start-up to large multinationals. These programmes seek to foster a dynamic, agile, and inclusive innovation ecosystem, with the aim of helping businesses develop and exploit their innovation, both domestically and on the global stage. Innovate UK is a key delivery body for the Government's Innovation Strategy for the UK to be a global hub for innovation by 2035.

<https://www.ukri.org/councils/innovate-uk/>



FastBlade tidal turbine blade test facility (Credit: University of Edinburgh)



UK Marine Energy Council (MEC)

Launched in 2018, the UK MEC acts as the voice of the UK's tidal stream and wave energy industries. The UK MEC in 2023 organised roundtables with the Conservatives, Labour, Liberal Democrats and SNP bringing together industry leaders to communicate the progress that had been made and the challenges the sector faces. The MEC has played a leading role in ensuring policymakers are engaged and up to date with progress in the sector, and in the summer produced a barriers brief, which outline proposed solutions to the key barriers to the UK realising its marine energy potential.

In 2023 the UK MEC signed Memorandums of Understanding with Marine Renewables Canada to better facilitate information sharing and identifying areas where the associations could work together. The MEC holds the joint-secretariat of the Marine Energy All-Party Parliamentary Group in Parliament and is frequently invited to give evidence to select committees, and brief MPs ahead of key debates on renewables.

The MEC organised responses to key governmental consultations including on the Sustainable Industry Reward, changes to Allocation Round 6 and key devolved administration consultations including the Scottish Government's Draft Energy Strategy and Just Transition Plan, and the Welsh Government's Just Transition strategy consultation. The MEC also answered the UK government's call for responses to its Review of Electricity Market Arrangements (REMA), by emphasising that the current CfD mechanism does not account for the system benefits and subsequent cost reductions that ocean energy generation provides.

<https://www.marineenergycouncil.co.uk>

Wave Energy Scotland (WES)

Since 2014 Wave Energy Scotland has been applying Scottish Government funding to the technical challenges facing the wave energy sector, driving innovative technology projects towards commercialisation through a competitive stage gate process. Within the WES programme, separate funding streams have supported the development of novel wave energy devices, power take-off systems, control systems, quick connection systems and materials. The headline achievements of 2023 were:

- Completion of the demonstration of the AWS Waveswing device in Scottish waters;
- Support to the re-deployment of Mocean's Blue-X device;
- Demonstration of three mechanical and electrical quick connectors, by Apollo Offshore Engineering, Blackfish Engineering Design and Quocean;
- Conclusion of the control system development projects.

WES continues to support technologies emerging from the programme towards commercialisation and is delivering the EuropeWave device development programme in partnership with the European Commission, Ente Vasco de la Energía (EVE) and Ocean Energy Europe.

WES is analysing wave energy commercialisation pathways, in particular the opportunity for co-location and asset-sharing with the growing floating wind sector. A WES-commissioned study showed that such partnerships could offer up to 7% cost of energy reduction for wind projects and up to 40% saving for wave. In support of more radical cost-reduction opportunities, WES launched the Direct Generation programme, which is beginning to design concepts for flexible wave energy devices based on electrostatic power conversion technologies.

<https://www.waveenergyscotland.co.uk>



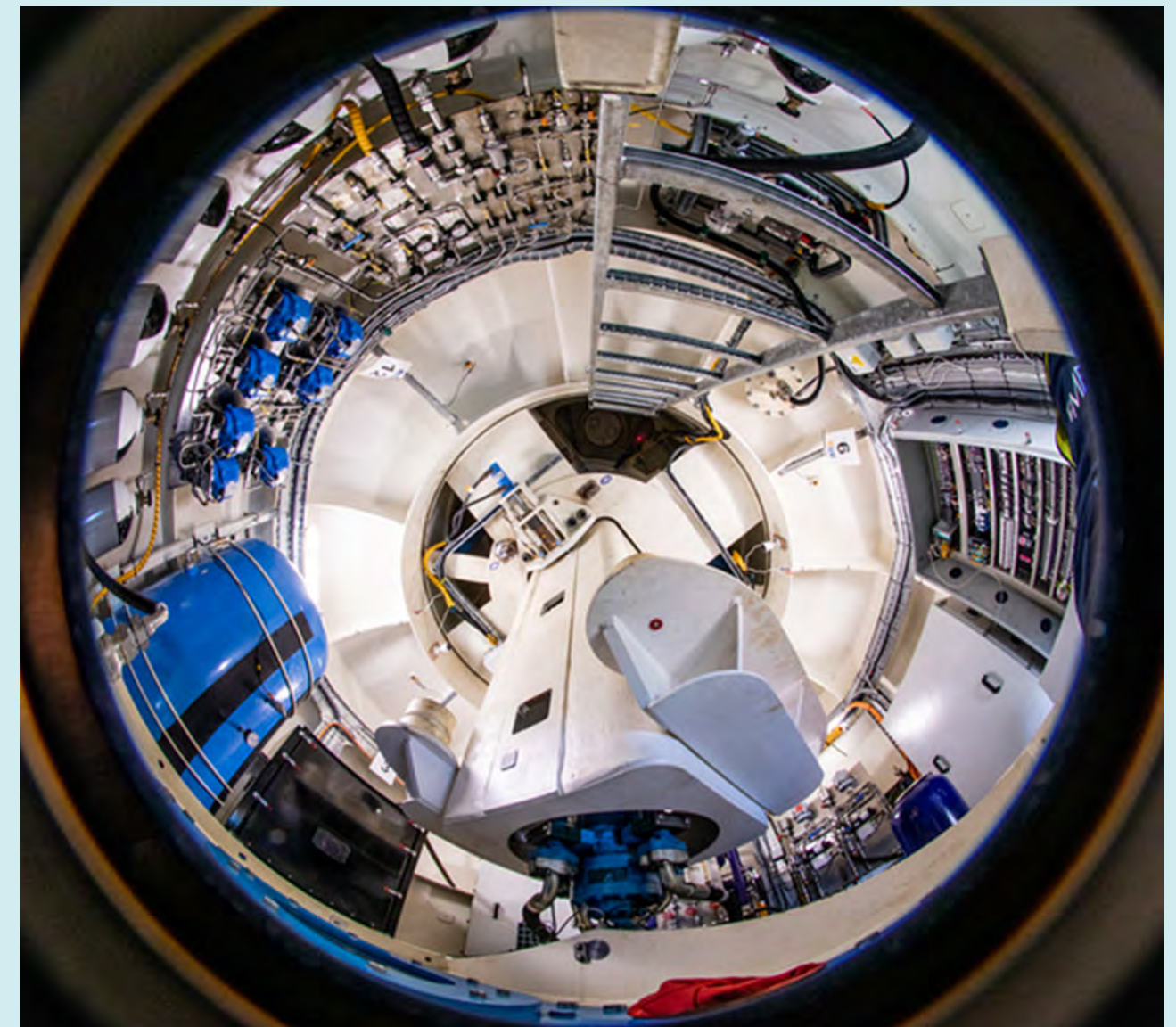
Testing multiple WECs on a floating-wind-scale semi-submersible platform at FloWave (Credit: Wave Energy Scotland)

Scottish Enterprise

Scottish Enterprise helps ambitious companies across Scotland grow by supporting businesses with innovation, investment and increasing their international competitiveness. In 2023, Scottish Enterprise led on delivery of the European Clean Energy Transition (CET) Partnership, a Horizon Europe partnership comprising of 30+ funding agencies from Europe and beyond, providing funding for trans-national collaborative R,D&I projects. The Scottish budget for the Joint Call 2023, which closed for pre-proposals in November 2023, is €5 million. The call includes opportunities for ocean energy under the call module "advances renewable energy technologies for power production". Results of the call will be published in June 2024.

Scottish Enterprise has also been supporting companies to speed-up the transition to a low carbon economy in manufacturing, through the Low Carbon Manufacturing Challenge Fund (LCMCF). This has resulted in several grant awards, including £499,500 for Mocean Energy and the detailed design, build and testing of key subsystems for their small-scale Blue Star wave energy machine. The LCMCF is administered by Scottish Enterprise and is part of Making Scotland's Future, a programme led by Scottish Government and delivered by a range of partners including Scottish Enterprise, to help Scottish manufacturers grow and thrive.

<https://www.scottish-enterprise.com>



An internal view of the AWS Waveswing device (Credit: Wave Energy Scotland)

3 RESEARCH & DEVELOPMENT



Nova Innovation turbine manufacturing (Credit: Nova Innovation)

3.1 KEY R&D INSTITUTIONS



Supergen Offshore Renewable Energy (ORE) Hub

The Supergen ORE Hub was established in July 2018 with £5 million of funding from the Engineering and Physical Sciences Research Council (EPSRC). It was subsequently awarded a further £4 million in June 2019, and recently secured a further £7.5 million in July 2023 for the second phase of its program. The Supergen ORE Hub provides research leadership to connect stakeholders, inspire innovation and maximise societal value in offshore renewable energy. The Supergen ORE Hub is led by the University of Plymouth, with co-directors from the Universities of Aberdeen, Edinburgh, Exeter, Hull, Manchester, Oxford, Southampton, Strathclyde, and Warwick.

Some key updates as announced by the organisation in 2023 are as follows:

- The Supergen ORE Hub Sixth Annual Assembly took place between 11 – 12 July 2023 at the University of Southampton, bringing together over 250 delegates from across the offshore wind, wave and tidal stream communities. Alongside the Annual Assembly, the annual early career researcher (ECR) Forum was held, bringing together 60 ECRs to discuss their latest research;
- The Supergen ORE Hub has awarded £799,000 to 10 research projects at UK institutions through its Flexible Funding scheme in 2023. The Flexible Funds are designed to support ambitious research in offshore renewable energy across offshore wind (fixed and floating), wave and tidal stream sectors. These recent awards bring the total investment into ORE research between 2018 and 2023 to £3.8 million across 40 projects, a total that has been matched by £4.4 million of industry support over the same period;

- The Supergen ORE Hub has awarded an additional £38,000 to 9 ECR projects at UK institutions through its Early Career Researcher fund. These recent awards bring the total investment into ECRs between 2018 and 2023 to £204,000 across 46 projects;
- The Supergen ORE Hub and the Policy and Innovation Group at The University of Edinburgh published two new studies titled “Research and Innovation for Wave and Tidal Stream in the UK and EU - A 2023 Summary” and “UK power system benefits through deployment of marine energy technologies” which quantified the potential economic and power system benefits that the UK stands to gain through the deployment of innovative offshore technologies;
- The Supergen ORE Hub attended COP28, where it launched a new briefing paper on the role of offshore renewable energy in supporting the delivery of Net Zero.

Throughout 2023 the Supergen ORE Hub has engaged with the UK offshore renewable energy community through 14 events and responded to a UK Government consultation on the introduction of the Contract for Difference (CfD) Sustainable Industry Reward Scheme within the CfD scheme. In addition, Supergen ORE held the first in a series of policy roundtable workshops with key UK and devolved administration Government bodies and funding and statutory stakeholders to develop and inform ORE policy programmes. The Supergen ORE Hub has also directly produced, or contributed via Flexible Fund awards, to over 50 new publications across the offshore wind (fixed and floating), wave and tidal stream sectors.

<https://supergen-ore.net>



ORE Catapult

The Offshore Renewable Energy (ORE) Catapult is the UK's flagship technology and innovation research centre for offshore energy and a key actor in helping to deliver the UK's Net Zero targets. ORE Catapult plans to accelerate the creation and growth of UK companies in the offshore renewable energy sector by combining their unique research and development capabilities and access to demonstration and testing facilities. In 2023 ORE Catapult celebrated its 10-year anniversary and its achievements since 2013 include supporting over 1350 Small Medium Enterprises (SMEs) with the development, demonstration and commercialisation of their technologies, as well as being at the heart of over £677 million of innovation projects by total value.

In 2023, as part of the Interreg funded TIGER project, the ORE Catapult produced the following report, "Tidal Stream Technology Roadmap". The report roadmaps tidal stream cost reduction via 10 key technology innovations and shows how cost reduction is crucial in enabling an accelerated growth trajectory for the sector. It predicts that tidal stream costs could reduce to £50/MWh by 2035 in a high technology innovation impact scenario, assuming timely and sufficient research funding is made available to deliver innovation development

Crown Estate Scotland commissioned ORE Catapult to conduct an in-depth survey of wave and tidal technology developers, project developers and key stakeholders and gather feedback on ways to finesse the present leasing arrangement for projects between 3 and 30 MW to maximise potential for commercialisation.

In 2023, ORE Catapult plans to launch the Marine Energy Partnership (MEP), a collaborative joint industry programme that aims to address sector-wide challenges to reduce marine energy costs, accelerate development and create opportunities for local supply chains. Key project themes of the MEP are: Technology Innovation; Project Development; Supply Chain and Volume Manufacturing; and Finance, Investment and Insurance.

<https://ore.catapult.org.uk/>

3.2 KEY R&D PROJECTS

In addition to many smaller studies, there were several significant ocean energy R&D projects funded by UKRI through EPSRC:



Bionic Adaptive Stretchable Materials for Wave Energy Converters (BASM-WEC)

Launched in November 2021 and running for three years, BASM-WEC is a £1 million project, led by Strathclyde University, with the aim of developing and testing new cutting-edge wave energy technologies that will help the UK achieve its Net Zero goal. BASM-WEC seeks to take inspiration from the flexible bodies and fins of aquatic animals to develop an analysis and laboratory

testing toolbox to reliably design, analyse, and process a new range of adaptive and stretchable materials and structures applicable to WECs. In early 2023, the University of Strathclyde held the 1st BASM-WEC workshop, with the aim of establishing a network in the field of flexible Wave Energy Converters (WECs).

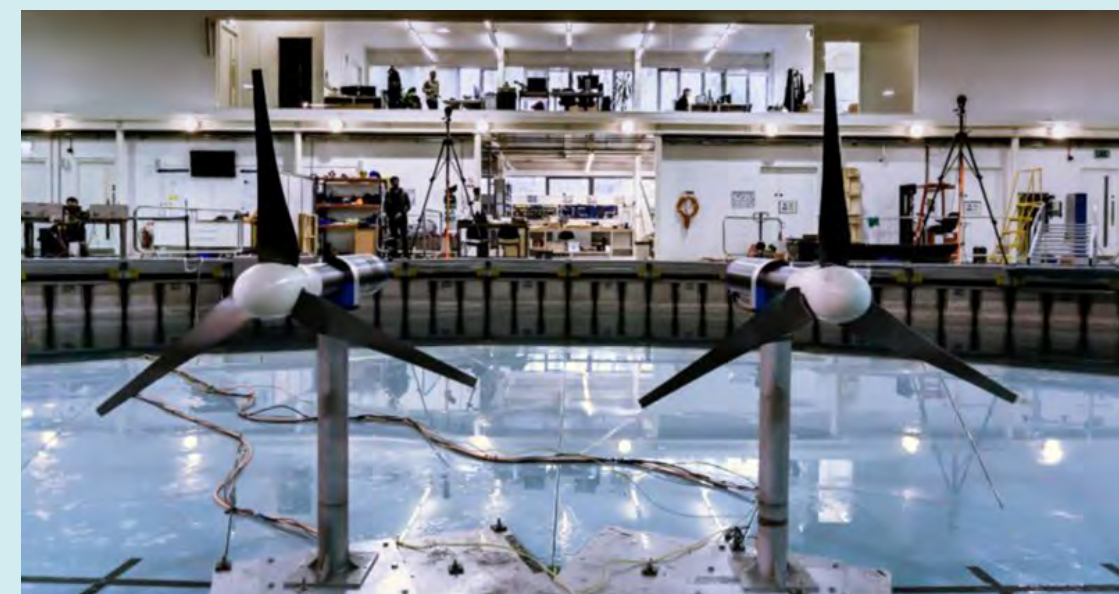
<https://basm-wec.org>

Co-Design to Deliver Scalable Tidal Stream Energy (CoTide)

CoTide is an ambitious 5-year programme (2023-28) with £7.4 million EPSRC funding to develop and demonstrate holistic integrated tools and design processes for tidal stream energy, helping to reduce costs and accelerate innovation. CoTide will integrate advanced hydrodynamics simulation and testing, corrosion and resilience modelling, novel composite materials, structural design and fatigue testing, leading to large scale demonstrations of advanced integrated systems using world-leading facilities FloWave and

FastBlade. CoTide brings together a team of around 35 researchers and academics from the world-leading centres at the Universities of Oxford, Edinburgh, Strathclyde and Sheffield to develop holistic integrated models covering all aspects of tidal stream turbine design from hydrodynamics, through structures and fatigue, to reliability. CoTide is supported by 25 project partners including 10 OEMs, utilities, standards agencies, and government agencies.

<https://cotide.ac.uk>



Turbines being tested at FloWave in CoTIDE (Credit: University of Oxford)

HAPiWEC

Holistic Advanced Prototyping & Interfacing for Wave Energy Control (HAPiWEC)

HAPiWEC is a wave energy research project, run in partnership by the University of Strathclyde and the University of Edinburgh, supported by industrial partners West Atlantic Marine Energy Community (WEAMEC), the National Renewable Energy Laboratory (NREL), Wave Energy Scotland (WES) and Renewable Dynamics. HAPiWEC aims to tackle the urgent issue of lowering the LCOE of wave energy to a level comparable with other commercialised renewable energy technologies by formulating more efficient control mechanisms that dramatically improve energy capture and device lifetime.

This project proposes that through the implementation of rapid prototyping hardware and remotely accessible user control, novel control algorithms can be demonstrated and validated at unprecedented levels of efficiency. The project aims to provide open access to the developed integrated WEC control system, on the hypothesis that through attracting new control ideas and widening participation, a further step change in the demonstration of WEC yield improvements and confidence in device survivability can be established.

<https://www.hapiwec.net>

FlexWave

FlexWave, led by the University of Plymouth and the recipient of funding from EPSRC, seeks to improve the design, manufacture and survivability of flexible WECs. FlexWave will investigate intelligent design concepts to explore whether different types of rubber, composites and polymers can be effective in improving performance, reliability and reduce costs compared to currently available materials. Testing will also include how materials hold up against extreme storms and sea conditions, which present a significant challenge to existing WEC designs. FlexWave will unite experts

in hydrodynamics, materials and deployable structures and conduct extensive design analysis and numerical modelling simulations of flexible fabric WECs, alongside physical tests in the COAST Laboratory. Researchers from both Plymouth and Southampton University will also work closely with the advisory board and wider industry to ensure any technology developed can be applied in real-world settings.

<https://www.plymouth.ac.uk/research/offshore-renewable-energy/flexwave>

Mooring Analysis and Design for Offshore WEC Survivability and Fatigue (MoorWEC)

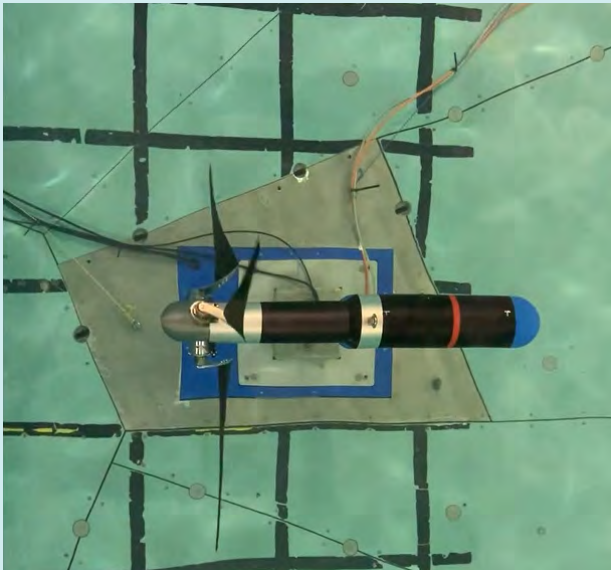
Led by University of Manchester in collaboration with Universities of Plymouth, Strathclyde, London City, and Exeter, MoorWEC will model the impact of waves on various mooring options to generate key information and efficient modelling methods to aid the design of future WECs. There is widespread consensus in the wave energy community that mooring system design and modelling is a major challenge that needs to be overcome. This is important because the mooring is the most vulnerable part of WEC's, which can be damaged by extreme waves, or the attrition caused by waves over time. Design, optimization, and assessment of mooring systems require efficient hydrodynamic and dynamic mooring models, which should be fully coupled to represent all interactions.

The project concentrates on the multi-float system M4 capable of MW capacity at full scale with some idealised analysis for a single float relevant to point absorbers. There is an emphasis on nonlinear elastic mooring/buoy configurations which reduce snap loads considerably. Breaking waves are an obvious concern and nonlinear wave fields are modelled and compared with wave basin data from Plymouth COAST and Edinburgh FloWave tanks. The aim of an effective efficient nonlinear wave multi-body mooring model and system identification is on track within a year.

Morphing Blades

Funded by the EPSRC, "Morphing Blades: New-Concept Tidal (and Wind) Turbine Blades for Unsteady Load Mitigation" aims to demonstrate, at model-scale, a novel technology to reduce unsteady-loading for tidal and wind turbines, improving resilience and reliability and decreasing the levelised cost of energy. Led by the University of Edinburgh and involving University of Bath and several UK based ocean energy developers, the project has been conducting tests at FloWave in Edinburgh in late 2023. The research resulted in a patent being filed and several scientific publications (most recently at EWTEC) and some journal articles in preparation. More tests of blades with a passive pitch are planned for spring 2024, as well as tests of a new-concept blade with a flexible trailing edge, which has also been recently patented by the Edinburgh team. Numerical simulations suggest that the proposed blades with the flexible trailing edge will allow similar performances to the passive-pitch blades.

<https://voilab.eng.ed.ac.uk/morphing-blades>



Morphing blades being tested on a tidal turbine at FloWave (Credit: University of Edinburgh)

MU-EDRIVE

Led by Newcastle University in collaboration with the University of Edinburgh and Mocean energy, MU-EDRIVE aims to establish the advantages of using electric power technologies in wave energy converters. Compared to electrical machines in other industrial sectors, wave energy converters are slow which has led to a range of novel generators being developed, yet comparatively few have been demonstrated at full scale with developers instead preferring to use conventional generators connected via device specific mechanical linkages. Pure electric drive train concepts are known to be efficient and mechanically simple but must now

be proved feasible and advantageous at a meaningful device scale. If the electrical generator is allowed to run flooded with sea water, there will be no requirement for sealing and therefore a much-reduced requirement for maintenance. The project will design and demonstrate direct drive power take off for subsea communication networks and also powering subsea equipment for the oil and gas industry. A full-scale electrical machine will be demonstrated using experience provided by an industrial partner. In addition, submerged electric generators will be demonstrated at sea for 12 months using Newcastle's USMART acoustic network gateway buoy.

WavE-Suite

Led by City, University of London in collaboration with the Universities of Bath, Edinburgh and Cardiff, WavE-Suite aims to provide robust modelling tools that can assess the survivability of WECs under the types of extreme marine environments that cause extreme loads and large responses. This project will develop a novel numerical modelling suite by combining different models and by proposing new numerical approaches and machine learning techniques, which will be more

accurate and require less computational effort. The modelling suite will be able to automatically go up to fully nonlinear simulations and down to linear simulations depending on the level of nonlinearity of waves and their interaction with the WECs. The new modelling suite will be validated by data measured from WEC models in the laboratory and real devices at sea and will be applied to assess the parameters relevant to the survivability and reliability of WECs.

The UK was also well represented in collaborative European projects, primarily funded through Horizon 2020 and Horizon Europe:

Element

ELEMENT, running from 2019 to 2023, was a €5 million EU H2020 project led by Nova Innovation alongside an international consortium of 10 partners. The ELEMENT team developed an advanced control system for tidal energy turbines that, by extending tidal turbine lifetime, improving efficiency and increasing availability, delivered a 17% reduction in the levelised cost of tidal energy. In

2023, the control system was trialled first on a 50 kW Nova Innovation demonstrator turbine deployed in the Étrel estuary, Brittany, before being rolled out in Nova’s Innovation’s Shetland Tidal Array.

<https://element-project.eu>

Enabling Future Arrays in Tidal (EnFAIT)

EnFAIT was a flagship €20 million EU H2020 project led by Nova Innovation and supported by six international partners, which ran from 2017 to 2023. It demonstrated development, operation and decommissioning at the world’s first offshore grid-connected tidal array of up to six 100 kW turbines, delivering a 40% reduction in the levelised cost of energy for tidal power. Following successful demonstration in 2020 of Nova’s first direct drive turbine (Eunice), activity in 2023 started with deployment of two additional direct drive turbines, turbines 5 (Grace) and 6 (Hali Hope) in January, making this the largest tidal array ever in terms of deployed devices. Turbines 5 and 6 are connected to shore via a

subsea electrical hub – the first time this has ever been successfully achieved for multiple tidal devices.

After a period of operating the full six turbine array, the initial three turbines were decommissioned in 2023, successfully completing the demonstration of the full lifecycle of a tidal energy project. The Shetland Tidal Array continues to set new benchmarks that showcase the growing maturity of the tidal energy sector. By December 2023 the array had extended its own world-record performance, achieving 72 months of continuous monthly power output to the grid. No negative effects on marine life have been recorded in over 12 years of environmental monitoring at the site.

<https://www.enfait.eu>



EnFAIT turbines 5 and 6 inspected by pupils from Cullivoe Primary School before installation (Credit: Nova Innovation)

EUROPEWAVE

Wave Energy Scotland (WES), Ente Vasco de la Energía (EVE) and Ocean Energy Europe (OEE) are currently delivering the EuropeWave wave device development programme. EuropeWave is a 3-phase programme co-funded by the European Commission which will lead to the deployment of three large-scale wave energy converters in 2025. In 2023, three Phase-3 projects were selected: CETO Wave Energy Ireland and IDOM will deploy devices in the Basque Country’s BiMEP test site and Mocean Energy will use Scotland’s European Marine Energy Centre site. The EuropeWave programme is

designed using the IEA-OES Evaluation and Guidance Framework. A second edition of the Framework was released in 2023, incorporating feedback from a range of adopters and explicit alignment with technical guidance from the International Electrotechnical Commission. Alignment with the IEA-OES recommendations will maximise further development opportunities of the EuropeWave technologies, helping them to demonstrate their technical qualities and future commercial prospects.

<https://www.europewave.eu>



Mocean Blue-X being tested in EuropeWave phase 2 (Credit: Mocean Energy)

EVOLVE

Results from the three main studies of the EVOLVE project were published in January 2023, highlighting the practical deployment potential, plus the system benefits both at a country and island level. GIS based modelling highlighted locations most suitable for wave and tidal energy technologies, in the three regions studied: Great Britain, Ireland, and Portugal. Power systems modelling for these three regions, using supply and demand profiles for credible future energy supply scenarios, quantified the benefits of ocean energy. The key result is that including a higher proportion of ocean energy within our future electricity mixes consistently results in higher renewable dispatch, for the same total renewable energy availability, due to the offsetting of wave and

tidal with wind and solar generation. The ability to dispatch more renewables results in lower fossil fuel and peaking plant dispatch, and thus lower total dispatch costs and carbon emissions. Similar results were shown at a micro-grid level, using the Orkney Islands as a case study. The EVOLVE project received support under the framework of the OCEANERA-NET COFUND project, with funding provided by Scottish Enterprise, Swedish Energy Agency and Fundação para a Ciência e a Tecnologia, with partners in the UK, Sweden, and Portugal.

<https://evolveenergy.eu>

FORWARD 2030

FORWARD 2030

In 2022, Orbital Marine Power and partners completed the design phase of the €26.7 million FORWARD-2030 project set up to deliver the accelerated commercial deployment of floating tidal energy. The FORWARD-2030 project consortium received €20.5 million grant support from H2020 to develop a system that will combine predictable floating tidal energy, wind generation, grid export, battery storage and green hydrogen production. As project coordinator and lead technology developer, Orbital Marine Power will oversee the installation of the next iteration of the company's turbine. This will feature a range of cost reduction innovations and be coupled with a hydrogen production and battery storage facility at EMEC. The project also will develop and assess large scale integration of tidal

energy to the European energy system, develop a smart energy management system and an operational forecasting tool. EMEC will host the demonstration, facilitate hydrogen production, deliver a comprehensive environmental monitoring programme, and develop a live environmental monitoring system and test programme. The University of Edinburgh will deliver techno-economic analysis of tidal energy, and the MaREI Centre at University College Cork will be responsible for addressing marine spatial planning issues for wide scale uptake of tidal energy.

<https://forward2030.tech>



Orbital O2 at the Fall of Warness (Credit: Orbital Marine Power)

LiftWEC

Concluding in March 2023, LiftWEC was a €3.4 million H2020 project led by Queen's University Belfast – Marine Research Group (QUB-MRG). The LiftWEC concept uses a unidirectional crossflow rotor to exploit hydrodynamic lift forces, extracting energy from the passing wave energy. The LiftWEC consortium aims to apply these concepts to the design of a 2 MW device, with the current study taking the design up to TRL4, including scaled tank demonstration and validation of numerical models.

The successful completion of the H2020 LiftWEC project is the latest milestone in the technology's development, proving the viability of the concept and identifying key research themes for further R&D to bring this technology closer to marine trials and commercialisation. The project has doubled the number of research papers on lift-based WECs, generated validation and code comparison datasets and continues to secure further research and innovation funding.

<https://liftwec.com>

MAXBLADE

Awarded in 2022 and launched at the University of Edinburgh's FastBlade test facility in early 2023, MAXBLADE is a €10 million project funded by the EU and UKRI. The project aims to investigate the performance and full lifecycle of tidal turbine blades from fabrication to decommission, embedding a circular economy element in their design. Working with tidal technology company Orbital Marine Power, the project will implement longer blade designs, increasing the swept area and reducing the overall cost of tidal energy. Innovations from MAXBlade will be integrated with

findings from its sister project, FORWARD2030, to enable large-scale production of Orbital's O2 turbine technology. MAXBlade is led by TechnipFMC and includes Orbital Marine Power, Marasoft, TECNALIA, The University of Edinburgh, EMEC, Laborelec and European Composites Industry Association. It is supported by Edinburgh University's commercialisation service Edinburgh Innovations.

<https://maxblade.tech>



Operations and maintenance of the Orbital O2 at sea (Credit: Orbital Marine Power)

MEECE

Marine Energy Engineering Centre of Excellence (MEECE)

MEECE was an ERDF funded project between the Offshore Renewable Energy (ORE) Catapult and the Universities of Swansea, Cardiff, Bangor, and Cardiff Metropolitan. At the point of its conclusion in

2023, MEECE had supported over 100 Welsh companies in the development of new products and services for the marine energy sector.

<https://www.meece.org.uk>

SEETIP Ocean

The Horizon Europe funded SEETIP Ocean project is coordinated by Ocean Energy Europe, involving the University of Edinburgh, Wave Energy Scotland, and other European partners. It supports the activities of the European Technology & Innovation Platform for ocean energy (ETIP Ocean) and the SET Plan Ocean Energy Implementation Working Group (OceanSET). These facilitate widespread knowledge-sharing within

the ocean energy sector and support the execution of the SET Plan Implementation Plan. In 2023, the project investigated best practice guidelines on community engagement and the future infrastructure requirements for ocean energy. Work also started on updating the Strategic Research and Innovation Agenda for Ocean Energy, due to be published mid-2024.

<https://www.etipocean.eu> and <https://www.oceanset.eu>

SELKIE

SELKIE

After four years, the SELKIE project concluded its collaborative mission to advance marine renewable energy in Wales and Ireland. A key achievement is the creation of open-source decision support tools, addressing challenges faced by early-stage developers and facilitating cost-effective development. These tools include a GIS Techno-economic calculator, Foundation and Mooring Design Tool, Generalised Actuator Disc CFD Tool, Converging Beam ADCP, Data Logger, Drone Methodology, and Operations Maintenance & Logistics Tool.

Dedicated to sustainability and innovation, SELKIE produced a comprehensive economic report on the offshore renewable energy sector, identifying strengths and challenges. The project also established a network of 100 SMEs in Ireland and Wales, fostering collaboration through events and workshops, marking a significant milestone in advancing marine renewable energy technologies and moving closer to commercialisation.

<https://www.selkie-project.eu>

Tidal Stream Industry Energiser (TIGER)

Led by ORE Catapult, TIGER was an ambitious €48.4 million project that concluded in 2023. TIGER has proved highly successful in influencing policy and driving the development of the Tidal Stream Energy sector on both sides of the Channel Manche. At the time of writing the UK has allocated £450 million to support Tidal Stream Energy under AR4 & AR5, while in France the FloWatt tidal project has received €65 million and revenue support to assist the continued development of la Raz Blanchard. Throughout the project, consent for six

turbine installations was achieved, with a further three planning applications submitted. TIGER partners have also manufactured & tested eight different tidal devices or components, with four of these being deployed at TIGER sites, including the QED Naval Subhub Community Demonstrator in The Solent. In addition, a cross-channel supply chain database, with over 5,000 registered companies, has been created, along with five Low Carbon Technology networks.

<https://interregtiger.com>



QED Naval's Subhub being towed to Langston Harbour for testing (Credit: QED Naval)

4 TECHNOLOGY DEMONSTRATION



Waverider buoy prior to deployment at EMEC (Credit: Colin Keldie)

4.1 EXISTING OPEN SEA TEST SITES

European Marine Energy Centre (EMEC)

2023 marked the 20th anniversary of EMEC, the world's leading centre for the testing and demonstration of wave and tidal stream devices in the sea. As a plug-and-play facility EMEC helps reduce the cost, time and risk of testing technologies offshore. EMEC provides pre-consented grid-connected demonstration sites in harsh wave and tidal regimes as well as scale test sites in gentler conditions for testing smaller scale technologies, subsystems and components. EMEC is the world's only accredited test facility for ocean energy, accredited by the United Kingdom Accreditation Service (UKAS), and is the first International Electrotechnical Commission (IEC) Renewable Energy Testing Laboratory for ocean energy. EMEC has hosted more ocean energy converters than at any other site and has been engaged in many of the live sea tests, demonstrations and deployments listed in this UK chapter.

As well as being an ocean energy test and demonstration site, EMEC has become a world-renowned innovation catalyst pioneering the transition to a clean energy future, instigating R&D and demonstration projects spanning green hydrogen, storage solutions, offshore and floating wind, maritime and aviation decarbonisation, and the wider energy transition. As well as operating its wave and tidal test sites, EMEC has also established an R&D hydrogen ecosystem, and in 2023 set out the needs case for a

National Floating Wind Test Centre in the UK. In 2023 EMEC's grid-connected Billia Croo wave test site was awarded a site-wide section 36 consent, further streamlining the consenting process for EMEC's clients, reducing the time and cost associated with offshore demonstration. The site has also been expanded by an area of 2.6 km² to the north-west enabling access to deeper water. Maximum installed generating capacity has been increased to 20 MW and a wider 'envelope' of device types and operations has been approved. Technologies over 1 MW can now demonstrate at the Billia Croo test site without having to apply for individual Section 36 consents.

2023 also marked the 10th anniversary of the International WaTERS (Wave and Tidal Energy Research Sites) network, established by EMEC to encourage collaboration, knowledge sharing and cross-border project development with ocean energy test centres around the world. Supported by IEA-OES, a new website was launched which includes a database of all operational and planned test sites. EMEC also hosted the latest International WaTERS workshop, with 30 delegates, representing 18 test centres and 5 observer organisations, from 10 countries, travelling to Orkney for site tours, workshops and discussions.

<https://www.emec.org.uk> and
<https://www.internationalwaters.info>



EMEC Caldale substation and storage site looking out to Fall of Warness (Credit: EMEC)

Morlais

The Morlais project, encapsulates 35km² of seabed around the promontory of Holy Island being developed by Mentor Môn. It boasts powerful tidal current resources and relatively low wave regimes, representing a prime site for future exploitation of tidal energy, and has been leased for 45 years. Infrastructure works to enable the export of electricity generated from tidal stream devices was completed in 2023, with

Welsh First Minister Mark Drakeford opening the onshore substation in October. Four developers have secured subsidy support under the Contracts for Difference (CfD) scheme in AR4 and AR5, namely Hydrowing, Magallanes Renovables, Môr Energy, and Verdant Isles.

<https://www.morlaisenergy.com>



Morlais onshore substation under construction (Credit: Morlais)

Marine Energy Test Area (META)

The Marine Energy Test Area, situated in the Milford Haven Waterway, is managed by Marine Energy Wales. It offers pre-consented 'Open Water' and 'Quayside' test sites. Aiming to bridge the gap between tank testing and the Welsh Demonstration Zones, this series of eight non-grid-connected sites is suitable for a range of wave and tidal component, sub-assembly, part-scale and full-scale device tests. In June 2023 after over a year of deployment the MEECE buoy was successfully decommissioned from the META Dale Roads site. The deployment involved testing various components, including a novel mooring damper and marine solar panels. There are now three projects in the water at META which include: A low carbon concrete experiment being conducted by Cardiff University looking at the

suitability of this material for tidal range schemes; A project investigating scour protection infrastructure habitat enhancements lead by Exo-Engineering; And an experiment exploring seaweed cultivation with consideration of colocation with ocean energy systems. In 2023 META also bolstered its equipment provision with wave buoys and a ROV which have proven to add considerable value to those testing at META. Currently booked in to deploy in 2024 are Dolphyn Hydrogen with a floating hydrogen production system designed to be coupled with renewable energy, and Swansea University with a multi-use tidal energy barge which can support different turbine designs.

<https://www.meta.wales>



Milford Haven Waterway (Credit: META)

4.2 ARRAYS AND DEMONSTRATION PROJECTS IN THE WATER

Tidal Energy

Magallanes Renovables

During 2023, Magallanes Renovables experienced a transformative year in the realm of tidal energy. Their groundbreaking efforts included the continuous testing of the ATIR, their 1.5 MW tidal energy device at the European Marine Energy Centre, marking a significant leap forward in harnessing tidal power. Furthering their technological prowess, the completion of the engineering phase for the second-generation ATIR 2.0 showcased their commitment to advancing tidal energy

solutions towards commercialization, as it will be installed in the new sites. They secured tariffs in the UK CfD auctions for two pivotal projects: a 3 MW expansion in Wales and a 1.5 MW contract in Scotland. These accomplishments not only underscore Magallanes Renovables' technical expertise but also solidify their pivotal role in driving tidal energy initiatives, setting the stage for a greener and more renewable future.

<https://www.magallanesrenovables.com>



Magallanes Renovables ATIR 2.0 render (Credit: Magallanes Renovables/D3 applied tech)

MeyGen

The MeyGen project, established in 2010 and situated in the Pentland Firth, is the largest tidal stream project in the world. The site has consent awarded for 86 MW, and the option to develop up to 398 MW. The current array has been in operation since 2018, with four 1.5 MW turbines. As of December 2023, MeyGen has delivered over 60 GWh of clean, predictable electricity to homes and businesses. Phase 1 incorporated two different turbine technologies, SAE's AR1500 and Andritz Hydro Hammerfest AH1000 MK1. The current turbines are consistently delivering availability >95% and have maintained continued production at 1.5 MW for >5 years without the need for recovery. The next phase of MeyGen

will deliver an additional 50 MW of capacity with a target commissioning date by 2028. Phase 2 successfully secured a CfD in AR4 for 28 MW at a strike price of £₂₀₁₂178.54/MWh and the other 22 MW at AR5 at a strike price of £₂₀₁₂198/MWh. The success at securing the consents and funding required to deliver this world leading project is a transformational moment for both the project and the industry. MeyGen is expected to deliver the world's first commercial scale tidal array and be a showcase for the whole sector.

<https://saerenewables.com/tidal-stream/meygen/>



AR1500 turbine being deployed by MeyGen (Credit: SIMEC Atlantis Energy)

Nova Innovation

In 2016, Nova Innovation installed the world’s first offshore tidal energy array, the Shetland Tidal Array, with three 0.1 MW turbines installed at Bluemull Sound in Shetland. The array was doubled in size under the EnFAIT project, and in 2023 the fifth and sixth turbines were installed, bringing the overall installed capacity to 0.6 MW and making this the largest ever tidal stream array in terms of installed devices. The three initial turbines deployed in 2016/17 were later decommissioned in 2023, completing the successful demonstration of all stages in the lifecycle of a tidal array. Nova is currently advancing the design for their next-generation tidal turbine under the UpTEMPO project. In 2023 Nova Innovation was awarded the SEASTAR project that will see an array of 16 Nova Innovation turbines deployed at the European Marine Energy Centre in Orkney. They deployed a 50 kW demonstrator tidal turbine at the Étrel estuary in France under the ELEMENT project. Nova have also initiated the GHOST project in Shetland to explore the supply of Green Hydrogen and Oxygen from Sustainable Tidal

energy, including the potential to generate energy and fuel for the Saxavord Spaceport. Finally, Nova has been actively collaborating with the Department for Energy Security and Net Zero as part of the CREATE project, with the aim of developing tools and techniques to reduce the cost of tidal turbine deployment and recovery.

<https://novainnovation.com>



M100-D tidal turbine “Eunice” before deployment
(Credit: Nova Innovation)

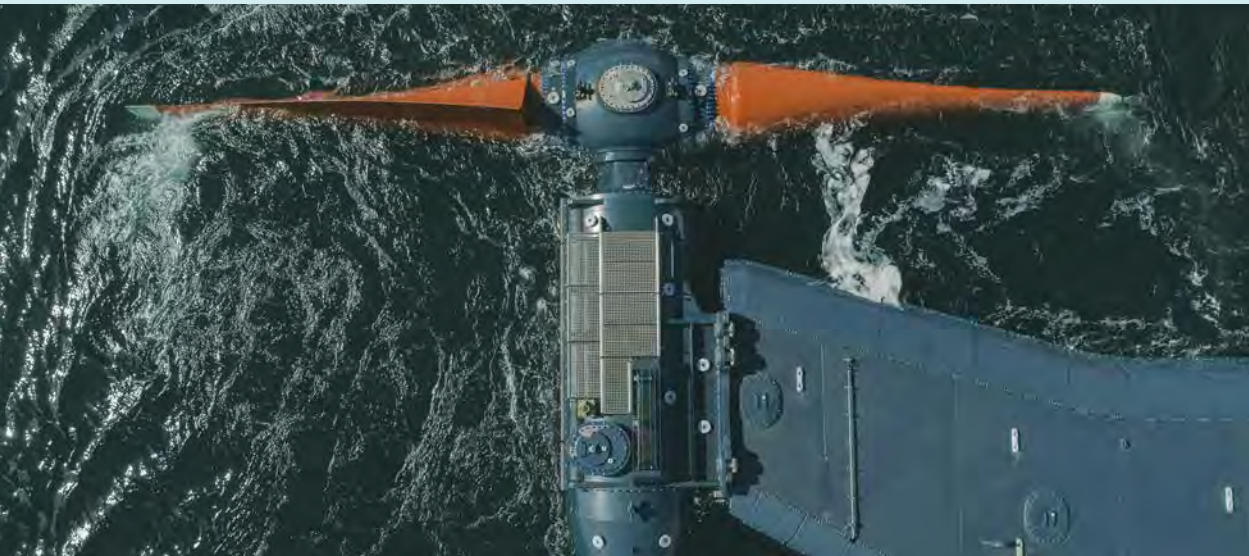
Orbital Marine Power

In March, Orbital announced that it had secured an option agreement from Crown Estate Scotland for a 30 MW project at the Westray Firth, Orkney. The project is currently under development with bird and marine mammal surveys ongoing and a grid connection agreement secured.

Orbital was awarded a further 2 CfDs totalling 7.2 MW in AR5, building on the 7.2 MW from the previous year’s AR4. These projects will be deployed alongside the current O2 tidal turbine at the European Marine

Energy Centre, Orkney and come on the back of the formal approval by Ofgem of a new transmission link to Orkney, which will unlock 220 MW of new renewables capacity in the islands. In December, Orbital was announced as the technology partner for Euclaire Tidal’s project at the Fundy Ocean Research Centre for Energy (FORCE), Nova Scotia, Canada. This project would initially involve a single 2.4 MW installation.

<https://www.orbitalmarine.com>



Orbital O2 turbine blade at EMEC (Credit: Orbital Marine Power)

Wave Energy

Mocean Energy

In 2023, Mocean Energy moved closer towards the commercial roll-out of its Blue Star technology (tens of kW) and prepared to scale up via its Blue Horizon technology (hundreds of kW), as it continues to learn by doing to implement its roadmap across different near- to longer-term markets. In 2023, Mocean’s prototype wave energy converter (WEC), BlueX, completed 10 months of operational time as part of the pioneering Renewables for Subsea Power (RSP) project. Under the remit of the Net Zero Technology Centre, RSP is demonstrating local, reliable, renewable power and communications provision from a WEC to a subsea micro-grid off the east coast of Orkney. Mocean has successfully demonstrated hybridisation of its hinged raft technology via the inclusion of solar panels on Blue X’s topside hulls, leading to an ocean energy product with boosted continuous power provision capabilities, essential to the off-grid use-cases. It is also a stand-alone example of the diversification advantages that a more diverse renewable

grid holds in store at larger scale. As well as robust wave and solar yields, and reliable remote control and communications, BlueX successfully survived and exported power during Storm Babet, with significant wave heights exceeding 7 m. Mocean Energy continues to advance step-change innovations, such as the novel Vernier Hybrid Machine technology, well suited to high-torque low-speed applications and bringing direct-drive electrical generators to the sector. Finally, Mocean continues to strengthen its commercial and industrial links, with memorandums of understanding signed with Tier I Aker Solutions and Dundee-based fabricator TEXO, both important steps in bringing the Blue Start technology closer to commercial deployment. 2023 also saw Mocean awarded £3.2 million to develop its Blue Horizon 250 kW WEC via EuropeWave.

<https://www.mocean.energy>



Onboard the Mocean Blue-X generating in rough seas of Storm Babet (Credit: Mocean Energy)

AWS Ocean Energy

By the start of 2023, AWS Ocean Energy had successfully completed at-sea testing of a 16 kW prototype of their Archimedes Waveswing wave energy converter at the EMEC Scapa Flow scale test site in Orkney, UK. The Waveswing is a modular, fully submergible, pressure differential absorber and this testing has proven the key technology sub-systems necessary to give confidence that the concept will work at full scale. Since completing device testing, AWS has continued to progress the design and feasibility

of large-scale multi-absorber wave energy platforms that makes use of the Waveswing technology. Finding a solution that addresses the fundamental challenge of scale, and the practicality of offshore maintenance, is essential to the delivery of affordable utility scale power. AWS is seeking partners to participate in the development and demonstration of a 2 MW multi-absorber pre-commercial prototype, whilst also pursuing other opportunities for deployment of smaller systems in bespoke applications.

<https://awsocan.com>



AWS Ocean Energy Archimedes Waveswing WEC (Credit: EMEC)

4.3 PROJECTS PLANNED FOR DEPLOYMENT

OceanEnergy

Irish wave energy developer, OceanEnergy, has signed up to demonstrate its 1 MW OE35 floating wave energy converter at EMEC. OceanEnergy intends to demonstrate the OE35 over two winter periods from 2024 at EMEC's Billia Croo wave energy test site. EMEC will support OceanEnergy with environmental monitoring. A series of field campaigns will include underwater and airborne acoustics, biophysical assessment of wave dynamics, fish aggregation and seabird analysis to assess the potential

interactions between local species and the operation of the technology. As an accredited test facility, EMEC will undertake technical inspection and performance assessment to confirm that the OE35 and moorings satisfies reliability, survivability and performance targets and adhere to IEC international standards. The demonstration is supported by the WEDUSEA project, co-funded by the EU Horizon Europe Programme and Innovate UK.

Tidal CfD projects

With the 41 MW CfD previously awarded in AR4, and the further 53 MW in AR5 announced in 2023, there is now a pipeline for 94 MW of tidal projects in the UK, expected to be commissioned by 2028 at Morlais, MeyGen and EMEC. This enhanced pipeline will help to increase

long-term confidence in the sector and provide industries that underpin the supply chains with increased visibility as to the needs of the ocean energy sector, reducing potential supply chain bottlenecks.



EMEC cable laying operations (Credit: EMEC/ Mike Brookes Roper)

5 SPECIFIC INITIATIVES FOR INTERNATIONAL COOPERATION

This is a non-exhaustive list of examples of different bilateral/regional cooperation initiatives involving the UK:

Clean Energy Transition Partnership (CETP)

The CETP programme is a transformative Research, Technological Development and Innovation (RTDI) program, designed to accelerate clean energy transition through annual funding calls. The CETP exists as an international collaboration involving 32 countries and over 50 funding agencies, supported through the Horizon Europe R&I programme. Within Government, Highlands and Islands Enterprise and South of

Scotland Enterprise. The CETP programme made up to £6 million available for support, with projects being awarded on a competitive basis. The programme closed in November 2022.

<https://cetpartnership.eu>

European Energy Research Alliance (EERA)

The UK continues to chair the European Energy Research Alliance (EERA) Ocean Energy Joint Program (JP), providing the UK the opportunity to continue to guide and assist in the development of the Horizon2020 and now Horizon Europe European funding and work programmes. Comprising of 9 full participants and 4

associate partners, the EERA Ocean Energy JP has identified areas of research, based on existing research roadmaps, which are considered critical for meeting the necessary requirements for the successful growth of the industry.

<https://www.eera-set.eu>

Ocean Energy Systems (IEA-OES)

Ocean Energy Systems (OES) is the abbreviated name for the International Energy Agency (IEA) Technology Collaboration Programme on Ocean Energy Systems. It is an intergovernmental collaboration between countries, founded in 2001, which operates under a framework established by the IEA. The need for technology cooperation was identified in response to increased activity in the development of ocean wave and tidal current energy.

The UK was a founding member of the IEA in November 1974 and has maintained a close relationship since then, utilizing its position of leadership to strengthen energy security, spur economic development and advocate for the implementation of cleaner forms of energy.

<https://www.ocean-energy-systems.org>

<https://www.iea.org>

6 RELEVANT NATIONAL EVENTS

Relevant events for the ocean energy sector that took place in the UK in 2023 include:

21-22 March – Marine Energy Wales Annual Conference, Swansea

10-11 May – All-Energy, Glasgow

25 May – Scottish Renewables Marine Conference, Edinburgh

11-12 July – Supergen ORE Hub Annual Assembly, Southampton

16 November – Wave Energy Scotland Annual Conference, Edinburgh

The UK will also be hosting a series of important events in 2024, including:

13-14 March – Marine Energy Wales Annual Conference, Swansea

15-19 April – Environmental Interactions of Marine Renewables Congress, Orkney

24 April – Supergen ORE Hub Annual Assembly, Plymouth

15-16 May – All-Energy, Glasgow

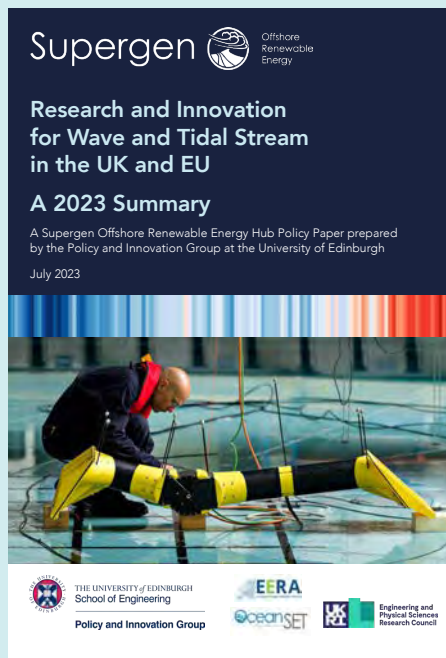
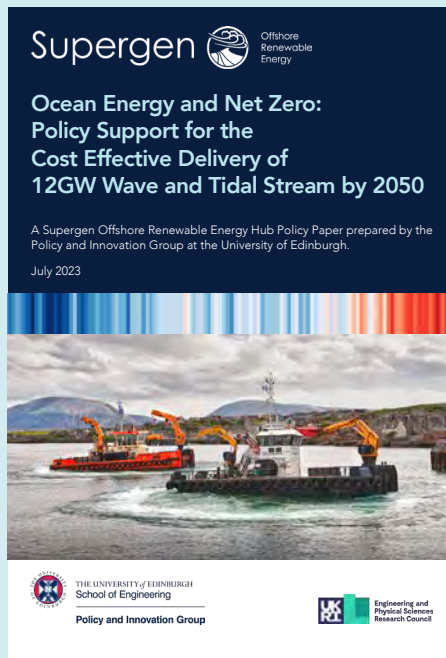
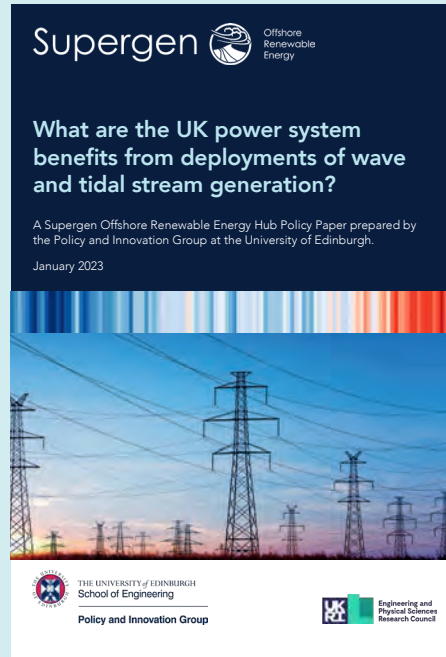
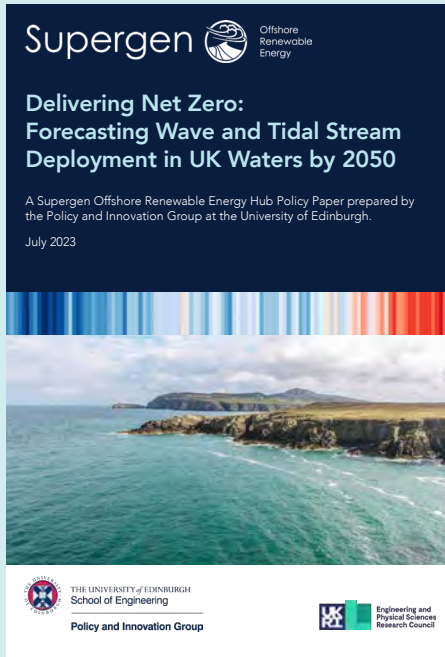
5-6 November – Ocean Energy Europe 2024, Aviemore



AWS Waveswing and EMEC test support buoy installed at EMEC Scapa Flow test site (Credit: EMEC)

7

POLICY GUIDANCE REPORT SERIES FOR THE UK WAVE AND TIDAL ENERGY SECTOR



Forming a clear, consistent and coordinated policy framework is a vital step in helping to accelerate the commercialisation and long-term viability of the ocean energy sector.

For prospective policy-makers, attempting to do so can raise many questions:

- What represents a realistic deployment target?
- What are the potential socio-economic benefits?
- How can ocean energy benefit the national energy system?
- How should future challenge areas be identified, targeted and budgeted for?
- Most importantly of all, what will be the costs and how will they be responsibly funded?

The Policy and Innovation Group, in collaboration with Supergen Offshore Renewable Energy Hub, has produced the Ocean Energy Policymakers Toolkit, a series of five policy guidance reports that aims to provide the answers to these questions.

This report series predicts that there is the potential for a future UK net zero energy system to have deployed up to 6.4GW of wave and 6.2GW of tidal stream by 2050. If these deployment targets are achieved, the UK has the potential to unlock over £40 billion worth of GVA for the UK economy as a result of domestic and international deployments. In addition to this, a commercial ocean energy sector also has the potential to bring a range of power system benefits. The unique energy generation profile of ocean energy technologies can lead to reductions of £1.03 billion per annum in the overall cost of electricity dispatch and can also help to underpin and strengthen an energy mix that will be dominated by intermittent energy sources, such as wind and solar. In short summary, a commercial ocean energy sector has the potential to create huge opportunities for UK commitment relating to Net Zero, the Just Transition and energy security.

However, realising these potential benefits will not be straightforward. This series continues by outlining the need for a balanced approach to the administration of both market pull mechanisms and technology push policy programmes. While market pull mechanisms, such as the CfD programme, have an important role to play in providing long-term financial support, the cost of providing this support is greatly dependant on the rate of technological innovation sustained across the sector, which is tied directly to the application of a comprehensive technology push policy programme. Finally, having identified the importance of technological innovation to cost-reductions, this report series provides an up-to-date summary of the main cross-cutting innovation challenges currently facing the sector

By utilising a combination of evidence-based future scenarios, quantitative analysis of existing data and active collaboration with industry and government policymakers, this report series has outlined how ocean energy, specifically the wave and tidal stream sector, can grow to become an indispensable feature of our future UK energy mix.

Scan the code to download all five reports from:



<https://policyandinnovationedinburgh.org/policymakers-toolkit.html>

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Deployment of Nova Innovation turbine near the Shetland Islands (Credit: Nova Innovation)



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