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School of Engineering

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

2021



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The Policy and Innovation Research Group is part of the Institute for Energy Systems (IES), which is one of the six research institutes within the School of Engineering at the University of Edinburgh. The group combines expertise on technologies, energy system organisations and institutions, and the wider policy and regulatory context for energy. They apply a range of quantitative and qualitative research tools and methods including innovation systems, energy system modelling and scenarios, and transitions management. This leads to preparation of strategy and investment roadmaps for organisations' funding, public and private investment and government departments.

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

Energy Technology Partnership

The Energy Technology Partnership (ETP) is the Scottish academic research pool in energy, an autonomous alliance of 14 independent Scottish Higher Education Institutions providing world-class capability and resources in energy RD&D, supported and co-funded by the Scottish Funding Council. With areas of energy expertise grouped under specific themes, including marine energy, ETP's vision is to build on the existing areas of excellence and collaborative working to ensure that Scotland remains a globally competitive driving force in energy research & innovation.

Find out more about ETP at <https://www.etp-scotland.ac.uk/>

Supergen ORE Hub

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 Hub provides research leadership to connect stakeholders, inspire innovation and maximise societal value in offshore renewable energy.

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

This report has been collated and edited by Henry Jeffrey from the Policy and Innovation Group and Kristofer Grattan from Edinburgh Innovations on behalf of ETP. This work also features in the International Energy Agency Ocean Energy Systems Annual Report 2021.

Cover Images:

Upper left: Orkney vessels trials project (Credit: Aquatera)

Bottom: Mocean Energy's Blue X wave energy device (Credit: Mocean Energy/Colin Keldie)

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1 OVERVIEW

With the eyes of the world focussed firmly on Glasgow for the hosting of the 26th UN Climate Change Conference, there hasn't been a better opportunity to review the current status of the UK's ocean energy sector. Despite being a challenging year, 2021 saw sustained innovation and cross-border collaboration, leading to continued offshore testing and deployment of state-of-the-art ocean energy devices. The UK continues to be recognised as a global leader in the wave and tidal energy sector, both in terms of its natural resources and in its technical capabilities [1]. As a result, the UK ocean energy sector continues to move from strength to strength; Orbital Marine Power's O2 tidal turbine has commenced generation at the European Marine Energy Centre (EMEC) in Orkney; Nova Innovation's confirmed expansion of the world's first tidal array in Shetland and demonstration of an electric vehicle charging point powered entirely from a tidal energy source; and the ORE Catapult led Tidal Stream Industry Energiser (TIGER) project to evidence tidal stream cost reduction continues to make steady progress. The UK Environmental Audit Committee's Call for Evidence on tidal energy also emphasised the need to capitalise on and support the substantial potential of the tidal sector to contribute to the UK's renewable energy mix and the socio-economic benefits associated with it [2]. However, despite the progress made there is still a pressing need for a reduction in the overall costs of marine energy for the sector to become competitive with alternative low-carbon technologies and contribute meaningfully to the UK's 2050 net-zero targets [1].



Launch of the Orbital O2 (Credit: Orbital Marine Power)

Wave

Throughout 2021, the wave energy sector continued to engage in innovative R&D to drive the sector towards higher TRLs and commercialisation:

- Wave Energy Scotland (WES) has maintained its position as the central focus for wave energy R&D activity in the UK and has helped to bolster confidence in the industry as two of its pilot projects, AWS Ocean Energy and Mocean Energy, moved towards and achieved real sea testing, respectively.
- EMEC welcomed Mocean Energy's Blue X wave energy prototype to their Scapa Flow test site in June 2021 for initial sea trials. The 10 kW device completed 154 days at sea, delivering steady outputs of up to 5 kW.
- In 2021, Europewave announced the projects that have been successful in progressing through stage 1 of its innovative Pre-Commercial Procurement process, which will eventually culminate with wave energy developers testing at EMEC and the Biscay Marine Energy Platform.

Tidal Stream

2021 was a strong year for the continued commercialisation of tidal stream devices, with a number of industry milestones achieved:

- Orbital Marine Power's 2 MW tidal stream turbine, the O2, was successfully towed to Orkney in April and has since commenced operation at EMEC's Fall of Warness test site.
- Magallanes second generation 2 MW tidal platform, ATIR, was successfully reinstalled at EMEC, supported by the Interreg NWE Ocean DEMO project.
- The Perpetuus Tidal Energy Centre (PTEC), a planned development for a large-scale tidal energy site off of the Isle of Wight, continued its collaborative work with EMEC. This sends clear market signals that there is an increasing appetite to commit resources to the tidal stream sector in the UK. PTEC have also entered into an agreement with Orbital Marine Power to utilise its O2 tidal stream turbine to deploy 15 MW by the end of 2025.
- Nova Innovation successfully deployed its commercial direct-drive tidal turbine 'Eunice' in its Shetland Tidal Array. In August it was announced that Nova had secured £2m funding from Scottish Enterprise for its VOLT project, which aims to develop Europe's first assembly line to mass manufacture tidal turbines.
- There is continued high-level, cross-country collaboration between the UK and France to deliver the TIGER project, the largest Interreg project yet awarded at €45.5m. The project aims to drive the growth of tidal stream energy in the UK and France with significant economic benefits for coastal communities and the planned installation of 8 MW of tidal energy capacity by 2023.

2 SUPPORTING POLICIES FOR OCEAN ENERGY

2.1 National Strategy

Energy policy within the UK is made more complex by the presence of devolved administrations, who have differing levels of autonomy. On a national level, matters of energy policy are mainly devolved to Northern Ireland and partly devolved to Wales and Scotland. The responsibility for enacting policy designed to tackle climate change is devolved to Wales, Scotland and Northern Ireland, however the UK government retains control over many energy and emissions reductions policy areas [3].

United Kingdom

The Climate Change Act (2008) set in legislation the UK's approach to tackling and responding to the global climate emergency and sets the UK's long-term legally binding target to achieving Net Zero emissions by 2050 [4]. The UK is committed to maintaining a robust and resilient climate policy framework that ensures global temperature rise is limited to 1.5°C. Within the UK, the responsibility for tackling climate change and developing energy policy lies with the Department for Business, Energy and Industrial Strategy (BEIS). BEIS has a wide policy remit that covers energy and clean growth, science, research and innovation and climate change [5]. The Department's energy-related strategic objectives are to:

- Ensure the UK's energy system is reliable and secure;
- Deliver affordable energy for households and businesses;
- Support clean growth and promote global action to tackle climate change

In line with its decision to host COP26, the UK government has set out plans to establish the UK as a world leader in green energy, bolstering its commitment towards net-zero emissions by 2050 with a series of high-level policy papers published by BEIS.

- “The Ten Point Plan for a Green Industrial Revolution”, published in 2020, laid the groundwork for ambitious policies and significant new public investment, while seeking to mobilise private investment [6].
- The “Net Zero Strategy: Build Back Greener”, published in 2021, aims to keep the country on track for meeting the UK carbon budgets, our 2030 Nationally Determined Contribution, and net zero by 2050. In addition to this the 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 our net zero targets [7].

The UK government has also adopted the Committee on Climate Change's Sixth Carbon Budget into law, placing the UK firmly on the path to reaching net zero emissions by 2050, with robust reduction targets also set for 2030. The Sixth Carbon Budget acknowledged that there continues to be a requirement for large-scale funding to bring nascent renewable technologies, such as wave and tidal, to fruition [8]. The government has also indicated that accelerated renewable deployment will be achieved by continuing the support offered by the CfD scheme, with the fourth allocation round offering a total of £285m [9]. This represents the largest commitment yet by the government and is considered crucial to fulfilling the ambitious targets to double the capacity of renewable energy secured in the 2019 round.



Cardinal Buoy at EMEC Billia Croo Wave Test Site (Credit: EMEC)

Wales

The Welsh Government remains committed to unlocking the energy potential contained in Welsh waters by supporting the delivery of marine energy projects [10]. In March 2021, the Senedd Cymru approved a net zero target for 2050, compared to 1990 levels [11]. Wales also has a target of producing 70% of its electricity needs from renewable resources by the year 2030 [12], with an aim of capturing at least 10% of the potential tidal stream and wave energy off the Welsh coastline by 2025 [13]. Current European Regional Development Fund (ERDF) grants support a number of projects aimed at establishing Wales as a centre for marine energy production. This includes the Marine Energy Test Area (META) and Morlais test and demonstration zones, as well as technology developers such as Bombora, Minesto, Nova Innovation and Marine Power Systems.

Marine Energy Wales (MEW) is the industry-led stakeholder group representing the wave, tidal and floating offshore wind industries in Wales. 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. To date, over £150m has been spent in Wales on the development of the marine energy industry, also including supply chain and academic research interests [14]. This included an investment of £29.1m over the last year, indicating that the sector continues to grow and show resilience in spite of the economic uncertainty brought on by COVID-19 [14]. This success is owed in part to the rising domestic interest in the sector, supported by a comprehensive government led policy drive. The MEW 2021 State of the Sector report details that 20 emerging renewable energy developers are actively progressing projects in Wales and that 465 MW of marine energy sites have been leased in Welsh waters [14].

Wales continues to build a pathway towards the commercialisation of the sector, with leading marine energy developers Bombora and Minesto establishing assembly and export centres close to the Pembrokeshire and Morlais Array Demonstration Zones [14]. In addition to this, Wales has invested £8.5m into the development of a national test centre network; the Marine Energy Test Area at Milford Haven; the TIGER tidal test site at Ramsey Sound; and the ORE Catapult delivered Marine Energy Engineering Centre of Excellence [15]. These will continue to attract not only the interests of UK based technology developers, but also continue to nurture successful international relationships.

Major developments with benefits for marine energy in Wales announced in 2021 include:

- The launch of the Welsh Government's Marine Energy Programme: Tidal Lagoon Challenge, inviting parties to submit expressions of interest for tidal range projects in Wales [16].
- The Climate Change Ministry in Welsh Government, which brings together key government departments to ensure a cohesive approach to Wales's climate change response [17].
- Consents secured for META, Wales' National Marine Energy Test centre and the Morlais Tidal Array Demonstration Zone [18]
- Welsh Government's ongoing commitment in their new Programme for Government in support of the marine energy sector [19].
- A dedicated pot for tidal stream energy in the CfD allocation round.
- Welsh Government's Deep Dive into Renewable Energy, highlighting a series of recommendations to reduce barriers and enable the accelerated development of the sector [20].
- In December the Welsh Government announced its intention to establish an emerging marine technology revenue support mechanism to sit alongside the UK Government's CFD [21].



The Morlais Tidal Energy Zone (Credit: Nova Innovation)



Mooring in Tidal Flow at EMEC Fall of Warness tidal test site (Credit: EMEC/Colin Keldie)

Scotland

The Scottish Government has committed to achieving net zero emissions by 2045, compared to 1990 levels [22]. In December 2020, the Scottish Government updated its Climate Change Plan, outlining a desire to implement a green recovery from the COVID-19 pandemic and charting a pathway to the emissions reductions set by the Climate Change (Scotland) Act 2019 [23]. This included a successful call for reform of the UK Government CfD mechanism to deliver focussed support for marine energy generation, an issue on which the Scottish Government has worked closely with the marine energy industry for a number of years [23].

Scotland's transition to net zero is supported by the Scottish Energy Strategy, published in 2017, which sets out the Scottish Government's vision for the future of the energy sector until 2050 and includes a target to meet the equivalent of 50% of Scotland's heat, transport, and electricity consumption from renewable sources by 2030 [24]. The Scottish Government will support the continued growth of the marine renewables sector with a strengthened framework of support, to be outlined in a refreshed Scottish Energy Strategy in 2022 [25]. The creation of the role of Cabinet Secretary for Net Zero, Energy and Transport in 2018, currently held by Michael Matheson MSP, has elevated issues regarding the renewable energy industries, climate crisis and net-zero policy to the cabinet level [26].

The Scottish Government has a strong track record of promoting the marine energy sector over the last two decades, supporting RD&D activities designed to maintain Scotland's position as a world leader in the marine sector. Since 2014, the Scottish Government has invested nearly £50m in its internationally recognised WES programme [27].

This has resulted in the deployment of a prototype wave energy device from Mocean Energy and the planned deployment of AWS Ocean Energy in 2022, both at EMEC, and the launch in 2021 of the EuropeWave programme in partnership with the Basque Energy Agency. The Scottish Government's Saltire Tidal Energy Challenge Fund, supported the deployment of major tidal stream projects by Orbital Marine Power and Simec Atlantis Energy [28]. The Scottish Marine Energy Industry Working Group provides a forum for the sector to speak with one voice about its priorities and the collective actions needed to maintain Scotland's competitive advantage [29]. As part of this, a number of industry-led subgroups are exploring key opportunities and barriers to the sector's continued growth.

At a national level, marine planning in Scotland's inshore and offshore waters is governed by the Marine (Scotland) Act 2010, establishing a legislative framework to ensure that increasing demands for the utilisation of the marine environment are managed responsibly and sustainably [30]. Crown Estate Scotland is a public corporation that holds responsibility for the licensing of renewable energy generation in Scotland's offshore waters. All revenue profit generated by Crown Estate Scotland is returned to the Scottish Government and capital is reinvested in the Scottish Crown Estate, with £11.5m returned in the 2020/21 financial year to aid in public spending and Scotland's green economic recovery [31]. In February 2021, Crown Estate Scotland published their first Climate Change Action Plan and directly acknowledged the significant potential value offered by focussed support and development of the wave and tidal sector [32].



Marine Energy Council

Since its formation in 2018 the UK Marine Energy Council (MEC) has facilitated collaboration between, and represented the interests of, leading wave and tidal technology and project developers, supply chain companies, consultants and renewable industry associations in the UK [33]. MEC has been instrumental in improving the policy landscape and outlook for the sector through coordinating engagement and communicating clearly to the UK Government, devolved administrations and other key stakeholders with a unified voice.

In August 2021, MEC hosted the then Energy and Scottish Ministers at the European Marine Energy Centre to highlight how the sector was strongly positioned to support the UK Government's aims:

- To deliver a green economic recovery by supporting a sector with a potential £1.4bn value to the UK economy by 2030
- Level up communities across the home nations creating 4000 jobs by 2030
- Support its Global Britain ambitions through accessing an export market estimated to be worth £76bn by 2050

The MEC also played a vital role in coordinating the ocean energy sector's overall position as to why it would be suitable to be included in a ring-fenced funding pot in the UK Government's newly restructured CfD scheme [34].

On the international front, to support collaboration and advance the sector's interests, MEC signed a cooperation agreement with Syndicat des Energies Renouvelables, in September 2021. The Franco-British collaboration will facilitate the sharing of analyses, best practice and formalises collaborative actions and synergies in realising the significant potential of renewable marine energies. 2022 will be a key year for the sector with the expected announcement of the CFD AR4 funding allocation in the summer, MEC will continue to advocate for increased R&D funding for wave technologies, work with the UK Government to establish a 2030 target for tidal stream and build support for Innovation Power Purchase Agreements.



COP 26

The UK hosted COP26 in Glasgow between 31st October and 12th November 2021, with the aim of bringing parties together to accelerate action towards the goals of the Paris Agreement and the UN Framework Convention on Climate Change [35]. In the lead-up to and at COP26, the UKRI Supergen programme hosted and participated in a range of engagement and communication activities on the role of offshore renewable energy in achieving net-zero greenhouse gas emissions, holding a public 'fishbowl' conversation to discuss net zero energy strategy [36]. The Scottish Government and Scottish Enterprise came together to host an event as part of 'Scotland's Climate Ambition

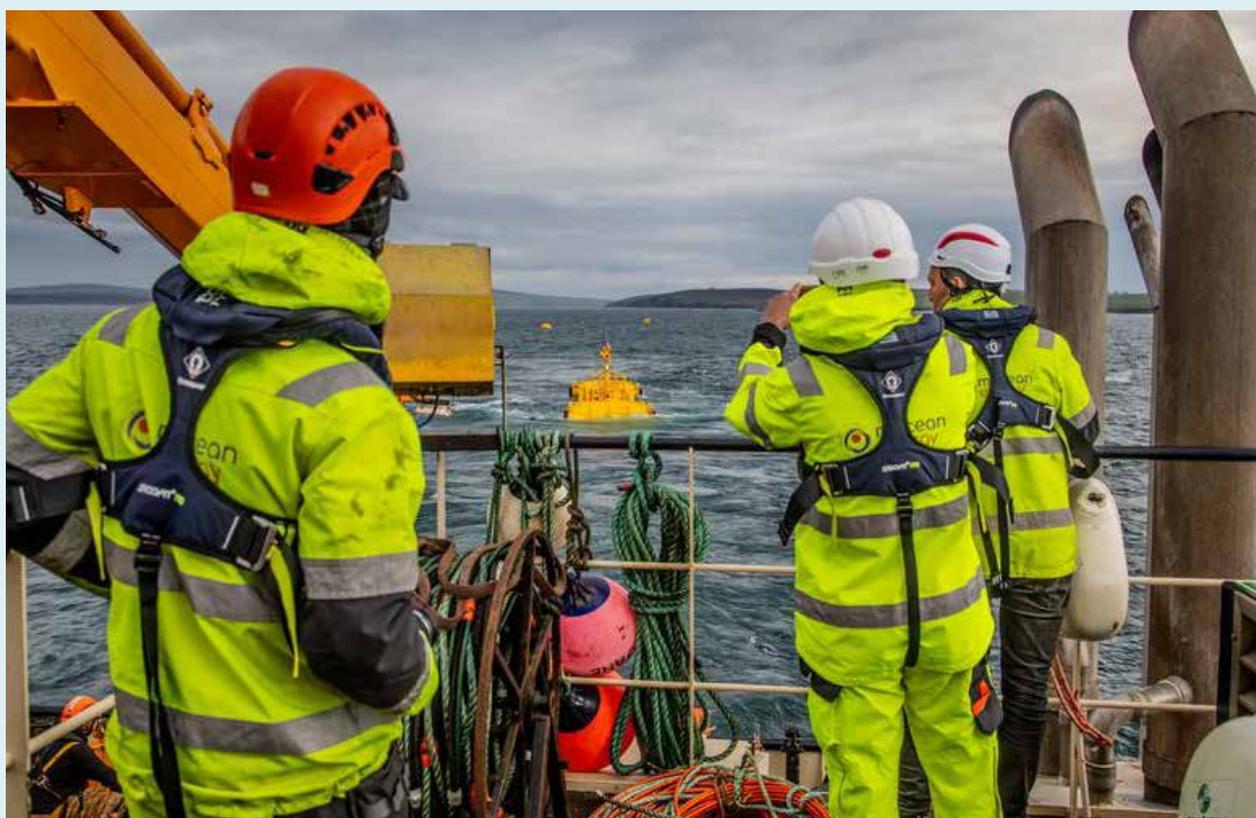
Zone', where UK marine energy developers were optimistic about deploying commercial devices by 2030, but urged government to offer similar support frameworks as have been seen for other renewable technologies [37]. COP26 was attended by many of the organisations listed in this report, providing an excellent platform to showcase the exciting progress made by the sector and presenting an opportunity to demonstrate why marine energy should play an increasing role in the domestic energy mix.

2.2 Market Incentives

Contracts for Difference

Contracts for Difference (CfD) scheme is the UK government's flagship program for supporting the generation of low-carbon electricity [38]. 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 three allocation rounds which have seen a number of different renewable energy technologies compete in auctions for a contract. Ocean energy technologies are however yet to gain a CfD through the competitive auction process, primarily because they have been in the same CfD 'pot' as established, mature technologies such as offshore wind.

In November 2021, the UK Government announced its biggest investment in a generation into tidal power, when it was announced that the fourth allocation round (AR4) of the CfD scheme, due to open in December and totalling £285m, will contain a £20m ring-fenced fund solely for the use of tidal stream energy projects [39]. This is in addition to £31m that tidal and wave developers can bid into as part of 'pot 2' in AR4 for emerging technologies. This provides the opportunity for the UK's marine energy sector to continue developing its technology and lower its operating costs at a rate similar to the countries world-leading offshore wind industry. The delivery of this fund is evidence of the strong collaborative atmosphere across the sector, that has witnessed many of the leading industrial actors, academic partners and policymakers working together to make the case for the much-needed investment in the marine energy sector.



Mocean Energy Blue X prototype under testing at EMEC (Credit: EMEC/Colin Keldie)

2.3 Public Funding Programmes

The UK government has made available a number of alternative public funding programmes to support the development of the ocean energy sector. Some of these initiatives are described in the following section.



UK Research and Innovation (UKRI)

In operation since April 2018, UKRI brings together seven research councils to support and coordinate research and innovation in the UK. Independently chaired, UKRI has a £8bn budget funded primarily through the Science Budget by the Department for Business, Energy and Industrial Strategy (BEIS). The research councils and bodies operating within UKRI are Innovate UK, Research England, Engineering and Physical Sciences Research Council (EPSRC), Arts and Humanities Research Council (AHRC), Biotechnology and Biological Sciences Research Council (BBSRC), Economic and Social Research Council (ESRC), Medical Research Council (MRC), National Environment Research Council (NERC), and the Science and Technology Facilities Council (STFC).

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

EPSRC

The Engineering and Physical Sciences Research Council (EPSRC) is the main funding body for engineering and physical sciences research in the UK, part of the UKRI. It was announced in 2021 that EPSRC will support 8 new wave energy converter research projects with a £7.5m investment [40]:

- Bionic Adaptive Stretchable Materials for Wave Energy Converters (BASM-WEC) – University of Strathclyde. EPSRC grant: £975,000
- Flexible responsive systems in wave energy - University of Plymouth. EPSRC grant: £984,000
- Holistic Advanced Prototyping and Interfacing for Wave Energy Control (HAPIWEC) – University of Strathclyde. EPSRC grant: £987,000
- Mooring analysis and design for offshore WEC survivability and fatigue (MoorWEC) – University of Manchester. EPSRC grant: £997,000
- MU-EDRIVE – Newcastle University. EPSRC grant: £776,000
- Wave-Suite – University of London. EPSRC grant: £987,000
- Novel high performance wave energy converters with advanced control, reliability and survivability systems through machine-learning forecasting – Lancaster University. EPSRC grant: £798,000
- System-level co-design and control of large capacity wave energy converters with multiple PTOs – Queen Mary University of London. EPSRC grant: £986,000

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

Innovate UK

A member of UKRI, Innovate UK is a funding body that supports businesses in their development of new technologies and concepts, helping them to reach commercial success. Innovate UK awards grant and loan funding across all sectors to business-led and high-value innovation in the UK. The organisation also cultivates networks between innovators and investors, researchers, industry, policymakers, and future customers on a domestic and international scale.

www.gov.uk/government/organisations/innovate-uk

Wave Energy Scotland

Wave Energy Scotland (WES) has continued to use Scottish Government funding to develop solutions to the technical challenges facing the wave energy sector. The WES programmes aim to drive innovative technology projects towards commercialisation through a competitive stage gate process. The stages of R&D activities guide projects from concept to prototype testing. Within the WES programme separate funding streams exist for the development of novel wave energy devices, power take-off systems, control systems, quick connection systems and materials. 2021 saw the successful deployment of Mocean Energy's half-scale Blue X wave energy converter at EMEC, and the completed construction of AWS Ocean Energy's WaveSwing device (ready for 2022 sea trials at EMEC), both of which received funding from WES [41]. WES has to date awarded £48M through 107 contracts, including 250 organisations from 13 countries [42].

www.waveenergyscotland.co.uk/



The Orkney Research and Innovation Campus (Credit: Orkney Council)

3 RESEARCH & DEVELOPMENT



3.1 Key R&D Institutions



Supergen Offshore Renewable Energy (ORE) Hub

The Supergen ORE Hub was established in July 2018 with an initial £5m of funding from the Engineering and Physical Sciences Research Council (EPSRC), and a subsequent second award of £4m in June 2019. Led by the University of Plymouth, the Supergen ORE Hub brings together expertise from multiple UK institutions including University of Edinburgh, University of Aberdeen, University of Exeter, University of Hull, University of Manchester, University of Oxford, University of Southampton, University of Strathclyde and University of Warwick. Some key updates as announced by the organisation in 2021 are as follows:

- The Supergen ORE Hub Third Annual Assembly took place virtually from 18 – 22 January 2021, bringing together over 475 delegates.
- In May 2021, it was announced that the Supergen ORE Hub had awarded almost £800,000 to 8 projects at UK institutions through its flexible funding scheme, designed to support ambitious research in offshore renewable energy.
- Across 2021, the Supergen ORE Hub awarded £66,700 to 17 projects at UK institutions through its Early Career Researcher fund.

- In September 2021, the Supergen ORE Hub and the Policy and Innovation Group at Edinburgh University, published a new study quantifying the potential economic benefit that the UK stands to gain through the deployment of innovative offshore technologies [43].
- Ahead of COP26, the Supergen Hubs (ORE, Bioenergy, Energy Networks, Energy Storage and Solar) hosted a net zero conference exploring the role of energy research in the pathway to net zero.
- Also ahead of COP26, the Supergen ORE Hub launched a briefing paper on the role of offshore renewable energy in delivering net zero [44].
- Throughout 2021, the Supergen ORE Hub has responded to the UK Government's successful CfD consultation, 'Floating Offshore Wind Market' Survey, 'Potential of Marine Energy Projects' call for evidence, 'UK Parliament call for evidence on Tidal Energy' and a response to the UK Energy White Paper.

<https://www.supergen-ore.net/>



The ORE Catapult

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. Since 2013, ORE

Catapult had supported 1040 Small Medium Enterprises (SMEs) with the development, demonstration and commercialisation of their technologies, engaged in 705 academic collaborations and been involved 1051 industry collaborations across the globe. ORE Catapult also leads on the TIGER project and is also involved in the Ocean Energy Scale Up Alliance (OESA) project.

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

3.2 Key R&D Projects

Floating Tidal Energy Commercialisation (FloTEC)

The FloTEC project, led by Orbital Marine Power and part-funded by a €9.8m contribution from the European Commission's Horizon2020 programme, finished in August 2021 after five years. The project sought to demonstrate the potential for floating tidal stream turbines to provide low-cost, high-value energy to the European grid mix. The project built on Orbital's existing floating tidal technology to develop and demonstrate the world's most powerful tidal stream turbine – the O2. The aim was to demonstrate an advanced, full-scale device in real conditions with high levels of reliability and survivability, while developing a greater understanding of factors such as installation, operation and decommissioning costs.

The Orbital O2 2 MW tidal energy turbine was deployed at EMEC's Fall of Warness grid-connected test site in Orkney in 2021 and is scheduled to operate at EMEC for the next 15 years. The O2 features a number of

innovations, including up to 50% greater energy capture through enlarged rotors with a lower rated speed, full onsite access to all turbine systems through an optimised platform configuration, high performance blades and compatibility with local supply chain and infrastructure [45]. Through a follow-on long term demonstration programme, a highly detailed dataset on power performance, component reliability and environmental monitoring will be gathered, while producing clean electricity for Orkney Island residents. With a focus on a design that avoids the requirement for heavy lift vessels and supports low cost and low risk installation and servicing, there are real hopes that the O2 will be a key enabling technology for the tidal energy sector and provide security to potential investors looking for low-cost tidal energy and future proofed design.

<http://www.flotectidal.eu/>



Orbital O2 operating at EMEC test site (Credit: Orbital Marine Power)

Enabling Future Arrays in Tidal (EnFAIT)

The EnFAIT project is a €20.2m flagship EU project, led by Nova Innovation, that has been running since 2017. It aims to demonstrate the development, operation and decommissioning of the world's first offshore tidal array (six turbines) over a five-year period to prove a cost reduction pathway for tidal energy that can make it cost competitive with other forms of renewable energy. By December 2021, the project has achieved the following:

- A 30% reduction in the cost of tidal energy, towards the 40% sought by December 2022
- 95% turbine availability against a target of 80%
- 18 months non-stop turbine operating period, against a target of 6 months
- A European supply chain that has grown from four countries to 19 countries
- No negative effects on marine life recorded in over 10 years monitoring of the site

The fourth turbine in the array – an innovative, direct drive, 100 kW “Nova M100D” model named “Eunice”, developed by Nova in the H2020 D2T2 project – has been deployed and operational at the site since 2020. The improved efficiency and reliability of the direct drive design has slashed the cost of energy by 30% compared to Nova’s previous, geared turbine model [46]. The M100D has operated fully automatically for over 12 months in the array, demonstrating exceptional performance, with availability >95% and no need for any interventions. A further two M100D turbines will be deployed in the site in 2022.



Nova Innovations M100-D tidal turbine 'Eunice' (Credit: Nova Innovations)

3.2 Key R&D Projects

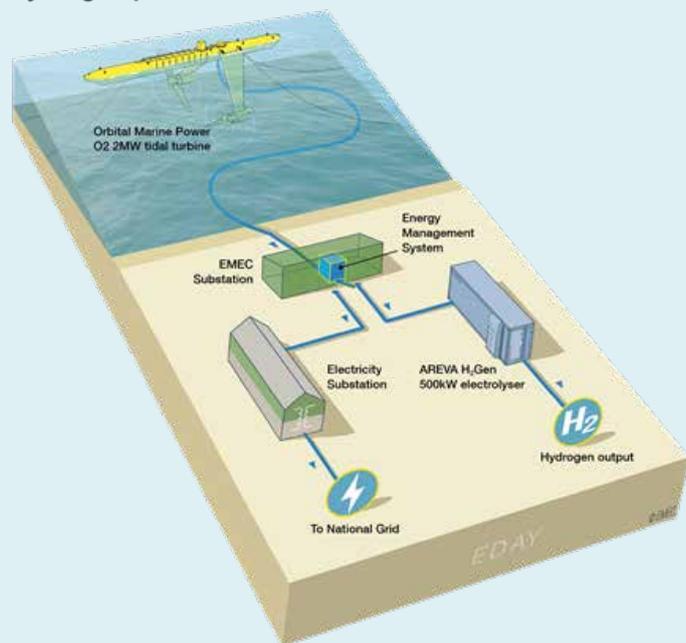
Integrating Tidal Energy into the European Grid (ITEG)

Funded by the Interreg North-West Europe programme and led by EMEC, the ITEG project has been running since 2017 and has received €11.79m of EU funding. The project seeks to address energy related carbon emissions in North West Europe by providing an integrated tidal and hydrogen solution for generating clean energy, that also tackles the grid export limitations faced in remote communities.

The integrated solution combines Orbital's next generation 2 MW floating tidal energy converter, the Orbital O2, with a custom built 500 kW Elogen electrolyser and an onshore energy management system (EMS), both of which will be deployed at EMEC's hydrogen production site on the Orkney island of Eday. The ITEG project brings together partners from across the UK, France, Belgium and the Netherlands. It aims to develop and validate an integrated tidal energy and hydrogen production solution for clean energy generation in remote areas, by opening new market opportunities for the ocean energy sector through hydrogen production and energy storage. It will also optimise the EMS and fast-track a clean energy generation, management and storage solution, while building a roadmap to support the replication of the integrated solution in other remote, grid-restricted areas.

<https://www.nweurope.eu/ITEG>

Integrated tidal energy and hydrogen production solution



ITEG project schematic (Credit: ITEG)



DTOceanPlus

This €6.7m European Commission funded project, culminated in August 2021 after three successful years. Led by Tecnalía, the consortium had 16 European partners, including, from the UK: The University of Edinburgh, WES, Energy Systems Catapult, Orbital Marine Power, and Nova Innovation. The project developed a suite of second-generation advanced design tools for the selection, development, and deployment of ocean energy systems. The tools were then demonstrated using the real projects and

technologies of the industrial partners. In September 2021, the open-source DTOceanPlus software suite was released along with associated documentation on GitLab, representing the culmination of the projects deliverables [47]. Additionally, a series of market analysis reports were produced during the project, published on the project website.

<https://www.dtoceanplus.eu/>

Strategic Environmental Assessment of Wave energy technologies (SEAWave)

The SEAWave project, coordinated by EMEC, aims to address long-term environmental concerns around the development of wave and tidal energy converters in the marine environment. The potential environmental externalities associated with the marine energy sector are generally site specific making it difficult to draw conclusions about a specific sector or impact pathway. SEAWave aims to address this shortfall by undertaking a gap analysis regarding the environmental impacts associated with deploying wave and tidal energy converters. The project is funded by the European Commission Europe an Maritime and Fisheries

Fund and is supported by a diverse range of project partners across the UK, Portugal, Finland, Belgium, Sweden and Ireland. Through April 2021, the SEA Wave project ran a series of sector-specific focus groups to raise awareness of online consenting resources and tools for use the marine energy community, helping to ensure the best available scientific evidence and tools are used during the consenting process.

<http://www.seawave-emff.eu/>



Marine Energy Alliance

The Marine Energy Alliance (MEA) is a European Territorial Cooperation project running from May 2018 to May 2022. The project has a total budget of €6m and is supported by Interreg North West Europe, who provide €3.6m of ERDF funding. The aim of MEA is to progress the technical and commercial maturity level of early-stage (TRL 3 – 4) marine energy technology companies with the overall goal of reducing the risk of device failure in subsequent demonstration phases. In 2021 it was announced that two MEA SME's, Mocean Energy and Waveram, had been selected to be part of

Europewave's Pre-Commercial Procurement (PCP) process. They will share a €2.4m budget alongside five other companies to further develop their wave energy device concepts in the first half of 2022. Through the Marine Energy Alliance (MEA) project, EMEC has been working with 16 early-stage technology developers to de-risk development prior to demonstration at sea, delivering a range of services aimed at aligning early-stage testing with international standards and providing technical assessments.

<https://www.nweurope.eu/projects/project-search/nwe-mea-north-west-europe-marine-energy-alliance/>



Ocean Power Innovation Network (OPIN)

The Ocean Power Innovation Network (OPIN) is an initiative running until 2022, which includes ORE Catapult and Scottish Enterprise as members. The project has a total budget of €2.6m, with €1.5m contributed by Interreg North West Europe from ERDF. OPIN is a cross-sectoral collaborative network that aims to accelerate the growth of the ocean energy sector and its supply chains across the partner regions of Ireland, the UK, Belgium, France, the Netherlands and Germany. The premise of OPIN is to encourage both cross-sectoral and cross-regional

collaboration for SMEs working in offshore renewable energy. OPIN will also create a forum for collaboration and technology exchange across the partner regions. Companies from regions with ocean energy expertise will interact with potential collaborators from regions that are world leaders in other technology fields, aiming to provide a mechanism to transfer expertise and address the disparities in innovation and economic development across north-west Europe.

<https://www.nweurope.eu/projects/project-search/opin-ocean-power-innovation-network/>



Ocean Energy Scale-Up Alliance (OESA)

Led by the Dutch Marine Energy Centre (DMEC), and involving EMEC and ORE Catapult, OESA is a three year pan-European project running until July 2022, with the aim of accelerating the development of marine energy technologies through strategic partnerships and international collaborations. With a total budget of €6.2m, where Interreg NWE provides €3.1m of financial support, the project partners encompass 13 European organisations specialising in offshore engineering, market

development and ocean energy testing and technology development. OESA seeks to accelerate the development, evaluation and promotion of a defined transnational scale-up offer, with promotion beginning in 2022. In addition, OESA aims to deploy four scaled-up ocean energy pilots to unlock up to 20 MW, with two pilots scheduled to deploy arrays in the next two years.

<https://northsearegion.eu/oesa>



Tidal Stream Industry Energiser (TIGER)

Led by ORE Catapult and involving EMEC and Orbital Marine Power, the TIGER project is an ambitious €46.8m project running from October 2019 until June 2023. With the European Regional Development fund contributing €29.9m of the overall funding, the project falls within the category for low-carbon technologies of the Interreg France (Channel) England Programme. The TIGER project aims to build testing and demonstration capabilities between the leading tidal turbine technology developers and tidal test sites across the Channel region. The ultimate aim of the project, the largest across the Interreg programme, is to utilise the learning

opportunities to make a stronger, cost-effective case for tidal stream energy as part of the UK/France energy mix. As a result the project will install up to 8 MW of new tidal capacity, ultimately producing a GHG reduction of 11,000 tonnes per annum and economic gains for coastal communities of around €13m GVA per annum. Additionally, the project has been supporting the growth of the tidal energy supply chain, coordinating a series of supply chain webinars, and working with the investment community to reduce risk and increase confidence in the sector.

<http://www.interregtiger.com/>



Ocean DEMO

Launched in January 2019 and funded by Interreg NorthWest Europe, the Ocean DEMO project is a €12.85m project. Built upon the FORESEA project, it aims to accelerate ocean energy's transition from single prototype to multidevice farms by providing free access to key European test centres: EMEC, DMEC, SEM-REV and SmartBay. In 2021, Ocean Demo awarded recommendations for support to 6 offshore renewable energy developers under its 4th call for applications. The following technology developers were recommended for

support packages, with two of them already starting testing in real sea conditions: Aquantis; Dutch Wave Power; LHYFE Labs; Mocean Energy; OV Wind and University of Edinburgh. The support packages provide a real boost to technology developers by allowing them to test their pioneering ocean energy technologies at sea, attract further investment and move along the path to commercialisation.

www.oceandemo.eu

Selkie

Launched in 2019, SELKIE is funded by the EU's Ireland-Wales co-operation programme and is led by University College Cork in partnership with Swansea University, Marine Energy Wales, Menter Môn, DP Energy Ireland and Dublin-based Gavin and Doherty Geosolutions. The three year, €5.2m project will see the development of a streamlined commercialisation pathway for the marine energy industry by establishing a cross-border network of developers and supply chain

companies in Ireland and Wales. In June 2021, Swansea University deployed a quarter scale converging beam acoustic Doppler current profiler through the support of the SELKIE project at META. In November 2021, an interactive workshop was held which provided experienced stakeholders with detailed descriptions of three new Selkie design tools.

www.selkie-project.eu



ELEMENT

ELEMENT is a €5m EU H2020 project running from June 2019 to May 2022. It is led by tidal energy experts Nova Innovation, with the participation of ORE Catapult and University of Strathclyde, as UK partners of an 11-strong international consortium.

As part of the rapid progress being made with tidal energy technologies, the consortium has identified an opportunity to improve performance using artificial intelligence. In a world-first, the ELEMENT team is using behavioural modelling and machine learning to control tidal energy turbines to improve efficiency and reduce costs.

This approach will reduce the dependency on external instrumentation and sensors which can struggle to withstand the immense forces exerted by the tides. As well as improving reliability and lowering costs, the project will turbo-charge the collection and analysis of ocean data at tidal energy sites, providing valuable learnings that can feed into turbine designs in the future. By extending tidal turbine lifetime, improving efficiency, and increasing availability, the project is expected to deliver a 17 per cent cost saving on the levelised cost of tidal energy.

element-project.eu

ELEMENT (Credit: Nova Innovation)

MONITOR

Finishing in December 2021, MONITOR (Multi-model Investigation of Tidal Energy Converter Reliability) was an Atlantic Area €1.6m Interreg-funded project led by Swansea University, which investigated the reliability of tidal energy converters, with a particular focus on identifying critical parameters for blades and support structures. The project partners, including EMEC and Ore

Catapult, studied monitoring systems suitable for the Magallanes Renovables S.L. and Sabella S.A.S. two tidal energy developers in the consortium. The monitoring system design changes focussed on lowering engineering safety factors, thus lowering the overall cost of tidal energy converters, while also improving reliability.

<https://www.monitoratlantic.eu/>

Wave Energy Scotland (WES)

2021 saw continued progress in the WES stage gate research, development, and innovation programmes, with a number of projects that WES are actively involved in achieving significant milestones. Mocean Energy's Blue X device completed a 5-month sea trial at EMEC and AWS completed construction of their WaveSwing device, ready for deployment at EMEC in early 2022. WES granted £1.8m to Apollo Offshore Engineering, Blackfish Engineering Design and Quoceant to demonstrate technology that enables the quick connection and disconnection of wave energy converters. It is expected that this will help to reduce operating costs, improve the

safety of offshore deployment and ultimately lower the overall cost of wave energy. WES supported the development of Tension Technology International's NetBuoy™ design tool and Arup's Convex concrete viability tool through its Structural Materials and Manufacturing Processes programme. Both tools will assist the sector to evaluate options to utilise lower-cost alternatives to steel structures.

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



Testing of Tension Technology International's NetBuoy™, funded by WES (Credit: WES)

EuropeWave

The EuropeWave project is a five-year cross-border collaborative R&D programme to advance designs for wave energy converter systems to a level from which they can be developed to commercial exploitation. The project, which is a partnership between WES and the Basque Energy Agency with match-funding by the European Commission via its Horizon 2020 programme, will invest almost €20m to procure R&D services that will lead to the at-sea deployment of scaled prototypes. The programme uses a “pre-commercial procurement” model, a multi-supplier multi-phase competitive process to

identify the most promising wave energy technology solutions from developers across Europe. EuropeWave announced the selection of the seven technologies to enter the programme in December 2021. The five most promising technologies will be selected at the end of phase 1 to progress to a second phase where project teams will undertake more extensive design, modelling and testing. A final phase will see three projects deploy their devices at test facilities off the coasts of the Basque Country and Scotland in 2025.

www.europewave.eu/

FORWARD-2030

Orbital Marine Power has announced that it will lead a pan-European consortium tasked with delivering the €26.7m FORWARD-2030 project, set up to deliver the accelerated commercial deployment of floating tidal energy. The FORWARD-2030 project consortium will receive €20.5m of grant support from the European Union’s Horizon 2020 research and innovation programme to develop a system that will combine predictable floating tidal energy, wind generation, grid export, battery storage and green hydrogen production. As both the project coordinator and lead technology developer, Orbital Marine Power will oversee the installation of the next iteration of the company’s turbine, which will be coupled with a hydrogen production and battery storage facility at EMEC.

LABORELEC will 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.

Website launch in 2022

4 TECHNOLOGY DEMONSTRATION



Waverider Buoy deployment at EMEC (Credit EMEC/Colin Keldie)

4.1 Test Centres & Demonstration Zones

The European Marine Energy Centre (EMEC)

Established in 2003, EMEC is the world's leading centre for testing and demonstrating wave and tidal converters. As a plug-and-play facility EMEC helps reduce the cost, time and risk of testing offshore with pre-consented grid-connected demonstration sites. EMEC is the world's only accredited test facility for marine energy, accredited by the United Kingdom Accreditation Service (UKAS), and is the first International Electrotechnical Commission (IEC) Renewable Energy Testing Laboratory (RETL) for ocean energy. EMEC has to date hosted the highest numbers of marine energy converters around the world [48].

In 2021 EMEC hosted demonstrations by Mocean Energy's Blue X wave energy converter at its Scapa Flow scale wave test site and has worked closely with AWS Ocean Energy to help gear up to deploy the Archimedes Waveswing WEC at EMEC in early 2022. At EMEC's Fall of Warness tidal test site, Magallanes Renovables reinstalled the 1.5 MW ATIR tidal platform in April 2021, and Orbital Marine Power began testing the new 2 MW O2 floating turbine. The EMEC-led Interreg Ocean DEMO project continues to support technology demonstrations across North-West Europe. As well as demonstrating ocean energy converter technologies, EMEC's sites have been busy with subsystem demonstrations and environmental monitoring activities including a series of acoustic surveys run by EMEC, a multi-sensor flow measurement platform by the University of Edinburgh, mooring solutions by TFI and InnoTECUK's robotic biofouling solution.

EMEC has continued to strengthen its international reputation, expanding its operations outside of Orkney: EMEC led the consenting works at the Perpetuus Tidal Energy Centre (PTEC) in the Isle of Wight which was granted planning permission in December 2021 making it eligible to bid into the UK Government's CfD scheme; and following EMEC being designated RETL status in 2020, EMEC delivered the world's first international power performance assessment for Verdant Power's New York tidal power array (delivered remotely due to COVID). EMEC continues to host the International WaTERS (Wave and Tidal Energy Research Sites) network to encourage collaboration, knowledge sharing and cross-border project development with ocean energy test centres around the world.

EMEC has grown and diversified over the past few years, with over 70 people now working at the test centre. Beyond wave and tidal energy, EMEC is also driving a wider R&D programme to develop a green hydrogen economy in Orkney, supporting various offshore wind projects and exploring the decarbonisation of the maritime and aviation sectors. The unprecedented activity that has taken place in Orkney has been a catalyst for economic development with the creation of well-paid jobs and a world-leading supply chain now exporting its skills and knowledge around the globe. An economic impact assessment has calculated EMEC added £306 million GVA to the UK economy between 2003 and 2019 [49].

<http://www.emec.org.uk/>

Wave Hub

Wave Hub is a pre-installed grid-connected site off the north coast of Cornwall for the testing of large-scale offshore renewable energy devices. Wave Hub is owned by Cornwall Council and operated by Wave Hub Limited. The site consent has been re-consented for floating offshore wind and is being sold off to a private buyer. As a partner to the £60m Pembroke Dock Marine project announced in June 2020, Wave Hub Ltd will deliver the Pembrokeshire Demonstration Zone (PDZ), a consented

and grid connected offshore test site. In 2021 Hexicon, a leading Swedish floating offshore wind technology and project developer, completed its acquisition of the Wave Hub test site from Cornwall Council, an acquisition that included a 25-year seabed lease option from The Crown Estate.

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



Perpetuus Tidal Energy Centre (PTEC)

The Perpetuus Tidal Energy Centre is a 30 MW commercial tidal stream project situated off the south coast of the Isle of Wight and will be England's first multi megawatt tidal stream power generation project. In December 2021, planning permission for the onshore elements of the ground-breaking tidal energy generation project was granted, meaning that PTEC now has all the consents in place to proceed with their proposal and will also be

eligible to bid for the newly restructured CfDs. PTEC, with consenting activities being managed by EMEC, has already signed an agreement with technology developer Orbital Marine Power to deploy its innovative and proven O2 turbine with the project. Onshore construction work is anticipated to commence in 2023, for completion by 2025.

<https://perpetuustidal.com/>

FaBTest

FaBTest is a 2.8km² test site in Falmouth Bay on the south coast of Cornwall with 10 years proven track record. The relatively sheltered location of the bay from the west allows for marine energy converter concept devices and components to be tested, whilst being occasionally exposed to more significant weather from the east. The

pre-consented site, leased from the Crown Estate, has a 9 metre 1-in-100-year return period significant wave height, and is highly accessible from Falmouth Harbour.

<http://www.fabtest.com/>

Marine Energy Test Area (META)

META, situated in the Milford Haven Waterway, is managed by Marine Energy Wales and is part funded by the ERDF through the Welsh government, the Coastal Communities Fund and the Swansea Bay City Deal. Aiming to bridge the gap between tank testing and the Welsh Demonstration Zones, these grid-connected sites will be suitable for a range of component, sub-assembly and marine renewable energy device tests including deployment and recovery and operation and maintenance

methods. As one of the partners in the £60m Pembroke Dock Marine Project, META will enable technology developers to test their marine energy devices close to their base of operation. In 2021, META signed a lease with The Crown Estate for the opening of the META Open Water test site, enabling the testing of wave and tidal energy devices in more energetic sites on Pembrokeshire's south coast.

<https://www.meta.wales/>



Quayside Test Site (Credit: Marine Energy Test Area)

Morlais Demonstration Zone (MDZ)

The Morlais Demonstration Zone (MDZ), located in West Anglesey, encapsulates 35km² of sea bed around the promontory of Holy Island. The zone, which has been leased from The Crown Estate for 45 years, boasts powerful tidal current resources and relatively low wave regimes, representing a prime site for future exploitation of tidal energy. The planning application for the MDZ has been recently approved by Welsh Government. The Environment Regulator, Natural Resources Wales, has also recently granted a marine licence to the development.

Subject to ongoing planning conditions being met, there is now strong hope that the physical development of the site will begin in early 2022, starting with establishing connectivity to the electricity grid. The MDZ has drawn interest from around the world, with seven developers and manufacturers having signed agreements for berths.

<http://www.morlaisenergy.com/>



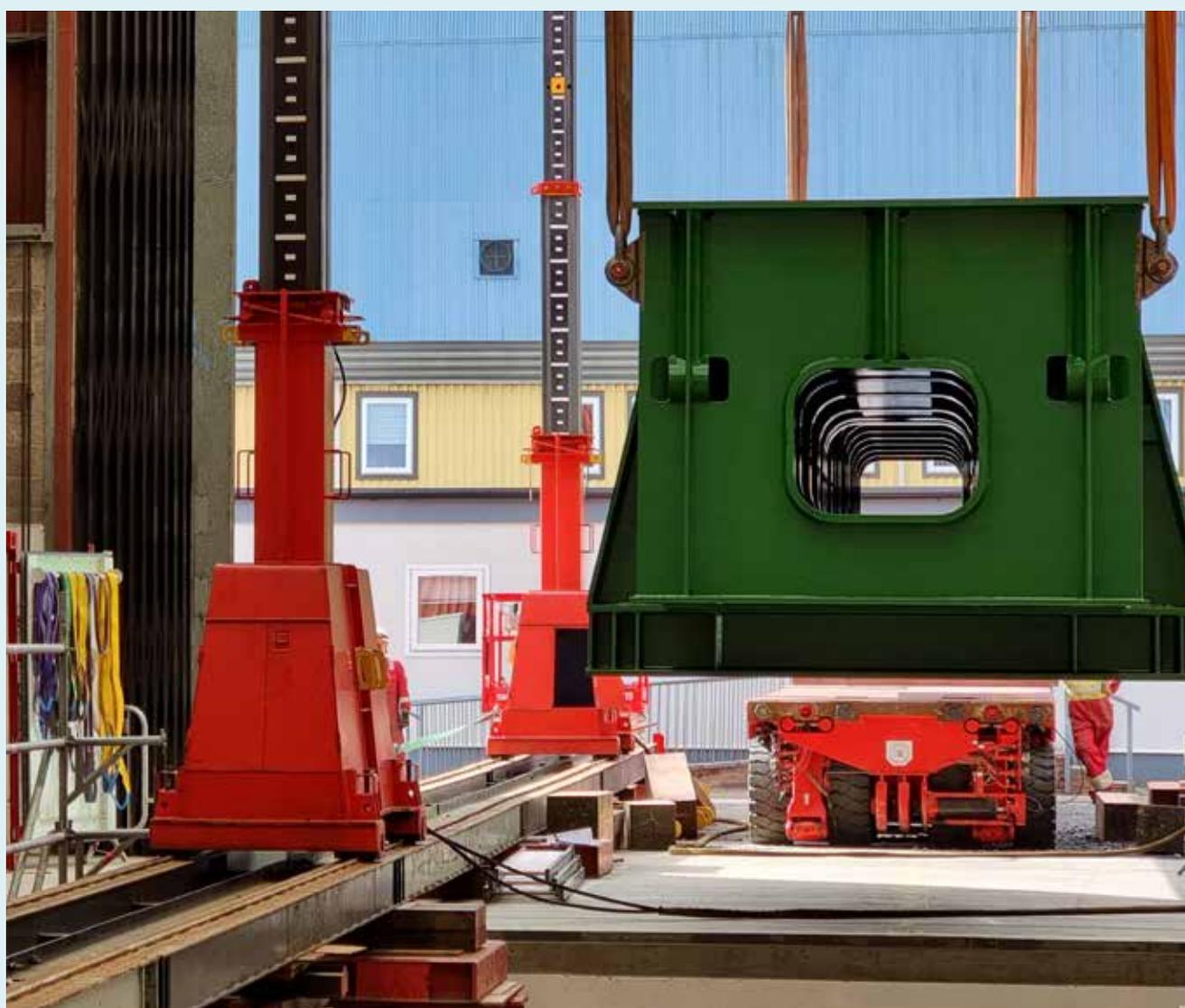
South side view of the Morlais Tidal Energy Zone (Credit: Marine Energy Wales)

FASTBLADE

Based in Rosyth, Scotland FASTBLADE is an innovative research facility that uses regenerative hydraulic technology to allow high-quality, low-cost accelerated testing of composite and metal structures including tidal blades, composite bridge sections and carbon fibre aircraft wing boxes. Developed by the University of Edinburgh, the facility will use a Digital Displacement regenerative hydraulic actuation system to reduce the energy requirements of fatigue testing. As the world's first dedicated fatigue test facility for tidal blades,

it will help secure Scotland's leadership role in marine energy. In 2021 major construction works on the site were completed and the building was handed over to Edinburgh University in October of that year. Commissioning has since been commenced on the hydraulic and electronic systems, with the first tests on a full-scale tidal turbine blade scheduled for 2022.

<https://www.fastblade.eng.ed.ac.uk/>



The reaction frame is lifted into position at the FastBlade facility (Credit: FastBlade)

4.2 Arrays And Demonstration Projects

This section is a non-exhaustive list of key projects tested, installed in the sea, and operating in 2021.

MeyGen

The MeyGen project is currently the largest planned tidal stream project in the world and the only commercial multi-turbine array to have commenced construction. The MeyGen array is owned and operated by SIMEC Atlantis Energy (SAE) in Scotland's Pentland Firth and comprises four 1.5 MW turbines, utilising Atlantis AR1500 and Andritz Hydro Hammerfest AH1000 MK1 turbines. In November 2021, SAE entered into a collaborative agreement with fellow world leading tidal energy developer, Nova Innovation, to work together to deliver tidal turbines at the MeyGen site and beyond.

Neighbouring the MeyGen site to the east is the Ness of Duncansby project which has the potential to support the installation of up to 100 MW of tidal energy capacity by 2024. Atlantis acquired the project in 2016 and plans to deploy AR3000 turbines which have a 26-meter rotor diameter and will be manufactured in Scotland.

<https://simecatlantis.com/projects/meysgen/>

Magallanes Renovables

Spanish tidal developer Magallanes Renovables' second generation tidal turbine device, the ATIR, was successfully deployed at EMEC's grid-connected Fall of Warness tidal test site in 2019. Funded by the Fast Track to Innovation pilot scheme, part of the EU's H2020 research and innovation programme, the device generated its first electricity into the UK national grid at EMEC in March 2019. In April 2021, after removal for optimisation, the 1.5 MW ATIR tidal generator returned to EMEC, where it was connected to the national energy grid, thus helping to demonstrate that it is possible to build, launch, install, operate and maintain a commercial tidal platform. Finishing the year on a high note, Magallanes has received a £1.2m grant by the British Energy Entrepreneurs Fund to design the next generation of the ATIR.

<https://www.magallanesrenovables.com>



Magallanes Renovables ATIR installation at EMEC
(Credit: EMEC/Colin Keldie)

Minesto

Swedish marine energy developer Minesto has had a physical presence in Wales since 2015, where its activities are focussed on verifying the functionality and power production of its Deep Green Technology at utility scale at their Holyhead Deep test site. Since May 2019, Minesto has received €14.9m of EU funding for the commercial development of its tidal energy scheme in Wales. There are hopes that the initial 0.5 MW Deep Green system will eventually be expanded into a 10 MW commercial array. In 2021 it was announced that Minesto had signed a two

year extension for its tidal energy site in the Vestmannastrandir strait, with analysis supporting a potential expansion from the current 200 kW site to a 4 MW commercial array. Finally, it was announced in September 2021 that Minesto will introduce a new range of power plants – the Dragon Class – an upgraded design of the company's Deep Green technology for predictable renewable electricity generation from tidal and ocean currents.

<https://minesto.com/>

Nova Innovation

In 2016, Nova Innovation installed the world's first offshore tidal energy array, the Shetland Tidal Array, at Bluemull Sound in Shetland. In 2018, Crown Estate Scotland granted an extension to Nova's existing seabed lease, increasing the overall potential capacity from 0.5 MW to 2 MW and extended the lease period until 2041. This extension allowed the progression of the EnFAIT project, with a further three 0.1 MW Nova M100 turbines to be installed between 2020 and 2022, bringing the overall installed capacity to 0.6 MW.

In 2021, Nova Innovation secured five new sources of funding to advance their innovative subsea tidal turbines.

- £2m of funding through Scottish Enterprise for their Volume Manufacturing and Logistics for Tidal Energy (VOLT) project.
- £6.4m from the Scottish National Investment Bank to fund manufacturing and distribution of its innovative subsea tidal turbines.
- £200,000 of funding from Innovate UK to deliver a feasibility study for a 7 MW tidal array in the Larantuka Strait in Indonesia, which could lead to delivery of the Indonesia's first tidal energy array.
- £800,000 through the BEIS Energy Entrepreneurs Fund in Nova Innovation's CREATE (Cost Reduction Acceleration in Tidal Energy) project. This project aims to slash the operation and maintenance costs of tidal energy in remote areas.
- €2.5m from the European Innovation Council Accelerator Fund to finance the UpTEMPO (Upscaling Tidal Energy Manufacturing and Production Output) project – a two-year campaign to design, build, and demonstrate an enhanced version of Nova's tidal turbine.

In 2021, Nova entered into a Memorandum of Understanding with SABELLA, a leading French tidal energy company, to accelerate development of tidal energy sites for both Scottish and French companies. Nova Innovation recently closed a secondary funding round on the online equity crowdfunding platform Seedrs, providing the opportunity for existing investors to realise a return from their investment. In 2021, Nova Innovations also announced plans for a project to produce Scotch whisky, with the distillation process powered by a tidal array placed in the Sound of Islay. In November 2021, Nova Innovation announced a collaboration agreement with Atlantis Energy, with the stated aim of turbo charging the domestic tidal industry and delivering more UK-built turbines. There is an initial focus to deliver Nova and Atlantis turbines at the MeyGen array in the Pentland Firth before moving on to international markets.

<https://www.novainnovation.com/>



Nova Innovations M100-D tidal turbine 'Eunice' (Credit: Nova Innovations)



Mocean Energy

Mocean Energy successfully deployed its first prototype device, 'Blue X', at EMEC in Orkney in June 2021. The project, funded through the WES's Novel WEC programme, provides learning towards Mocean's "Blue Horizon" technology for large-scale power and "Blue Star" device for subsea power applications. The Blue X was tested for 5 months, experienced sea states up to 2.3 m Hs, generated sustained power outputs of 5 kW, and provided invaluable data and learning towards

numerical model validation and future developments. Following the success of its prototype testing, the next step for Mocean Energy are to deploy Blue X along with subsea equipment to demonstrate reliable power and communications in a real-world application, further the development of the Blue Horizon technology through the EuropeWave programme, and commercialise the small-scale WEC product lines for launch in 2023.

<https://www.mocean.energy/>



Mocean Blue X at EMEC Scapa Flow test site (Credit EMEC/Colin Keldie)

Orbital Marine Power

In May 2021, Orbital Marine Power successfully installed the world's most powerful tidal stream turbine, the O2, at EMEC's Fall of Warness tidal test site and commenced generation of electricity to the local grid. The O2 represents the culmination of more than 15 years of innovation and development, demonstrating that the tidal energy sector is moving ever closer to commercial deployment. The O2 features a range of innovations focussed on driving down the cost of tidal stream energy, including twin 20m rotor diameters - the largest swept area on a single tidal energy converter to date, pitching hubs for floating tidal energy and a new 'gull wing' leg retraction system to allow low cost, onsite access to the

entire generating unit. The O2 project has been supported via funding from a range of collaborative partners including the European Union's Horizon 2020 research and innovation programme under the FloTEC and TOPFLOTE project, the Scottish Government's Saltire Tidal Energy Challenge Fund, and Interreg North-West Europe programme under the ITEG project. In October 2021, Orbital Marine Power was selected as one of only twelve companies to take part in the Global Investment Summit, a programme designed to showcase the most innovative green technologies and companies already operating in the UK.

<https://orbitalmarine.com/>



Orbital O2 at EMEC Fall of Warness test site (Credit: Orbital Marine Power)

Bombora Wave Power

Australian wave energy developer Bombora Wave Power has established its European operations in Pembrokeshire, Wales and is currently progressing the 1.5 MW mWave™ Pembrokeshire Demonstration Project supported by ERDF funding through the Welsh Government. In 2021 it was announced that Bombora Wave Power had received a subsidy from the Japanese Ministry of Economy, Trade and Industry to work with Japanese shipping giant Mitsui

O.S.K. Lines to evaluate the prospects of the wave energy business in Japan and Asia. It was also announced that Bombora has formed a strategic partnership with TechnipFMC to develop a floating wave and wind power project. The partnership will initially focus on TechnipFMC and Bombora's InSPIRE project.

<https://www.bomborawave.com/>



Bombora's full-scale 1.5 MW mWave prototype (Credit: Bombora Wavepower.)

Marine Power Systems (MPS)

In May 2021, Swansea-based wave energy developer Marine Power Systems confirmed that they have been successful in selecting the Biscay Marine Energy Platform (BiMEP) as the site for testing their grid-connected commercial megawatt scale device. Part-funded by the European regional Development Fund, this project will prove the reliability and effectiveness of their technology at scale, as well as supporting the certification process. In August 2021, MPS

were completed its crowdfunding campaign, raising over £4m from investors committed to helping MPS continue developing in the sector. Finally, in October MPS announced plans to work with London-based Marine2oto develop integrated solutions to support the production of green hydrogen utilising marine vessels to transport this energy vector to market.

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

4.3 Planned Deployments for 2022

AWS Ocean Energy

2021 has been an exciting year for AWS Ocean Energy, with completion of its prototype 16 kW Archimedes Waveswing wave energy converter in October 2021 and ongoing testing at the Muir of Ord ahead of its deployment at EMEC in January 2022. AWS's prototype Waveswing is a modular fully submersible pressure differential absorber, suitable for integration into multi-absorber platforms or single use in remote power applications. The development was the recipient of a £3.4m grant from the WES programme, highlighting

another successful instance of industry collaboration. The opportunity to test AWS's device at EMEC's Scapa Flow test site allows for validation of the devices performance and reliability, as well as providing valuable experience with regards to the manufacturing, installation, operations, and maintenance for this promising technology.

<http://www.awsocenergy.com/>



AWS Ocean Energy's Archimedes Waveswing arrives at EMEC (Credit: EMEC)

5 RELEVANT NATIONAL EVENTS

Relevant events for the ocean energy sector that took place in the UK in 2021 include:

18th – 22nd January – Supergen ORE Hub Annual Assembly, virtual

27th – 29th January – Marine Energy Wales Annual Conference, virtual

23rd – 25th February – International WaTERS (Wave and Tidal Energy Research Sites) workshop, virtual

23rd – 24th March – Scottish Renewables Annual Conference, virtual

11th – 12th May – The North Sea Decarbonisation Conference, virtual

23rd June – Scottish Renewables Marine Conference, virtual

18th – 19th August – All Energy

2nd September – Orkney International Science Festival, virtual

5th – 10th September – 14th European Wave and Tidal Energy Conference (EWTEC), hybrid

23rd September – FloTEC Webinar: Lessons learnt from developing the world's most powerful tidal stream turbine, virtual

1st – 12th November – Conference of Parties 26 (COP26)

The UK will also be hosting some important events in 2022:

18th – 20th January – Supergen ORE Hub Annual Assembly, virtual

22nd – 23rd March – Marine Energy Wales Conference 2022

11th – 12th May 2022 – All-Energy

25th May – Scottish Renewables Marine Conference



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