



ANNUAL REPORT

AN OVERVIEW
OF OCEAN ENERGY
ACTIVITIES IN

2018



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Disclaimer:

The Ocean Energy Systems (OES) Technology Collaboration Programme is part of a network of autonomous collaborative partnerships focused on a wide range of energy technologies known as Technology Collaboration Programmes or TCPs. The TCPs are organised under the auspices of the International Energy Agency (IEA), but the TCPs are functionally and legally autonomous. Views, findings and publications of the OES TCP do not necessarily represent the views or policies of the IEA Secretariat or its individual member countries.



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CHAIRPERSON'S MESSAGE

MR. HENRY JEFFREY

University of Edinburgh, United Kingdom
OES Chairperson

A warm welcome to the 2018 OES Annual Report and I trust that you will find it informative and useful.

I must start this year's Annual Report with the sad news of the passing of OES former chairman John Huckerby.

John Huckerby was nominated the New Zealand's representative to the OES Executive Committee by the New Zealand Government in 2008.

John served as Chair of the OES over 4 years (2009 – 2012).

During his mandate John submitted a new 5-year Strategic Plan to the IEA to secure a third 5-year mandate. John not only was responsible for producing a new 5-year Strategic Plan but it overhauled the OES 'brand', by updating its name, its logo and, its website.

John had a strong commitment to make OES "the authoritative voice on ocean energy". During his chairmanship he introduced a high sense of rigor in the OES activities and always guided the Executive Committee meetings in a very diplomatic and motivational way. He spread the OES all over the world, engaging with other international organizations and conferences promoting ocean energy internationally and will be fondly remembered by many people around the world.

For the content of this year's report, I would like to thank all the member countries for their contributions. The country reports included here convey that 2018 has seen significant progress internationally for ocean energy. Several tidal projects achieved extensive operating hours with multi-GWhs of generation being clocked up globally. Wave energy technology has progressed with a number of large-scale laboratory and offshore tests having been successfully undertaken.

Our 2018 feature article is an interview with Jonathan Hodges, Senior Innovation Engineer, of Wave Energy Scotland and Lauren Moraski of the U.S. Department of Energy's Water Power Technologies Office. Together, they have been leading international collaboration on the development of Stage Gate Metrics for Ocean Energy that will provide a robust and common approach to managing innovation. A further featured article is on the successful ICOE 2018 conference hosted in Cherbourg, France by Amandine Volard, ICOE Conference Manager, including a message from the Linda Church Ciocci, Chair of the ICOE 2020 to be hosted in Washington D.C.

Many key achievements for wave and tidal projects are discussed throughout this report with some of my personal highlights below. The US DoE announced funding of \$25m to support 12 next-generation marine energy technologies as well as enabling projects. In the UK, Orbital Marine Power concluded testing of their 2MW turbine and successfully raised £7m from 2,300 individual investors for a next generation device. Wave Energy



Scotland selected 2 devices to go forward to real-sea testing in 2020 with funding of £7.7m. In Europe there was further consolidation around three-bladed horizontal axis tidal turbines with vacant opportunities in France and beyond being actively pursued by other developers. In the southern hemisphere Australia is re-engaging with wave energy following the opening of Albany test site, led by Carnegie Clean Energy.

At a policy level ocean energy progresses within a global energy market that is seeing significant change. The imperative and drivers for renewable energy continue to increase whilst further downturns in the prospects for nuclear energy in key ocean energy markets are increasing headroom for low-carbon technologies. However, globally we are still waiting on clear market signals for ocean energy projects. Such market signals are vital for the industry to progress towards commercialisation.

In terms of the OES, 2018 saw progress made on a number of strategic tasks. The Stage Gate Metrics for Ocean Energy and Cost of Energy research is now being complimented by an assessment of employment and jobs stimulated by the sector. These strategic activities align with the OES Vision for International Deployment for Ocean Energy published in 2017 and which continues to drive OES's strategy.

Finally, I'd like to thank Annie Dallman from the USA and Yann-Hervé De Roeck from France for all of their excellent work as vice-chairs of the OES during 2018. Many thanks also to our Executive Secretary Ana Brito e Melo for all of her hard work in putting this report together.

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EXECUTIVE SUMMARY

ANA BRITO E MELO

OES Executive Secretary

“There are no quick fixes to long-term energy challenges. To find solutions, governments and industry benefit from sharing resources and accelerating results. For this reason the IEA enables independent groups of experts - the IEA Technology Collaboration Programmes, or IEA TCPs.”

INTRODUCTION

Ocean Energy Systems (OES) is the short name for the **Technology Collaboration Programme on Ocean Energy Systems** under the International Energy Agency (IEA).

This Annual Report presents an overview of progress made by the OES, including summaries of new, ongoing and recent projects, as well as updated country reviews prepared by the Delegates.

Interest and outreach for new membership within OES continued in 2018. Australia re-joined the OES in August and the Commonwealth Scientific, and Industrial Research Organisation (CSIRO) signed the Implementing Agreement on behalf of the Australian Government.

The OES is always looking for new members across the globe, and key representatives from potential new member countries are encouraged to attend meetings as Observers.

The OES has 25 members, which provide a broad international base of information, sharing experience and knowledge and further a diversified representation of interests: members are from governmental departments, utilities, universities and research organizations, energy agencies and industry associations. This is one of the benefits of joining OES: participants gain an international perspective on ocean energy issues, opportunities and present challenges.

The OES international co-operation facilitates:

- Securing access to advanced R&D teams in the participating countries;
- Developing a harmonized set of measures and testing protocols for the testing of prototypes;
- Reducing national costs by collaborating internationally;
- Creating valuable international contacts between government, industry and science;
- Sharing information and networking.

This Executive Summary provides a brief summary of the OES Annual Report for the year 2018. It synthesizes the main achievements in the OES collaborative activities and presents relevant policies, R&D activities and deployments in the water by each OES member country. It also includes, as in previous years, an interview on a specific topic, this year about performance metrics on ocean energy: Two experts from Wave Energy Scotland (WES) and from the U.S. Department of Energy (DOE) are invited to give their views on this topic based on the programmes being run by WES and by the Water Power Technologies Office (WPTO) within DOE where a formalized technology evaluation or stage-gate process is applied to measure the success of the technology and its development.

OES has a close link with the International Conference on Ocean Energy (ICOE), held every two years, and leads a competitive process to select host country teams. In 2018, the 7th edition of ICOE was held in France gathering 200 exhibitors and more than 3500 visitors from 36 countries. In this report, OES also interviews the past and current Chair (2020) of the ICOE to hear about the benefits of this event for the international ocean energy industry.

Interest and outreach for new membership within OES continued in 2018. Australia re-joined the OES in August and the Commonwealth Scientific, and Industrial Research Organisation (CSIRO) signed the Implementing Agreement on behalf of the Australian Government.

OES KEY ACHIEVEMENTS IN 2018

The OES held two ExCo Meetings in 2018: The 34th and 35th meetings were convened in Cherbourg, France (14 – 15 June 2018), and in Las Palmas on Canary Islands (29 - 30 November 2018). The meeting in Cherbourg was organised for the occasion of the International Conference on Ocean Energy (ICOE 2018) and the meeting in Las Palmas was hosted by the Oceanic Platform of Canary Islands (PLOCAN) and organised in the same week as the High-Level Conference of the Atlantic International Research Centre (AIR Centre).

The overall Work Programme of the OES is headed by an Executive Committee composed of representatives from each participating country and organisation, while the management of individual research projects or studies is the responsibility of Operating Agents. The present Programme consists in thirty Tasks, of which ten are currently operational.

During 2018, the OES project on **Environmental Issues** (known as Annex IV) led by the US Department of Energy (DOE) pursued a process for retiring, or putting aside, environmental risks that continue to slow consenting and hamper the development of marine energies. This process is made up of three parts: 1) Data Transferability and Data Collection Consistency; 2) Risk Retirement Pathway; and 3) Outreach and Engagement

with the MRE Community. Tethys, the online knowledge management system, continues to expand and increase user interactions. Last year, the publicly available collection of scientific papers, reports, and other media increased by 681 papers for a total of 4,723 entries. During 2018, a peer review process was completed for Tethys with feedback from the greater Tethys community online. Two workshops were organised: one on social and economic data to address consenting; and a second one on the data transferability and data collection consistency processes. Further 3 webinars were hosted during 2018. Annex IV continued to collect and update information on new wave and tidal projects as well as on-going research studies.

On the Cost of Energy for Ocean Energy Technology, further progress has been done during the year with a new study led by Tecnalia from Spain as a continuation of a previous one done in 2015. This new study monitors the evolution of ocean energy costs and assesses the impact of different drivers on the LCOE, by taking into account historical trends, future development and differences among technologies and countries.

OES has two tasks dedicated to the **modelling verification and validation**, one led by Ramboll, for wave energy, and a second one, for tidal energy, led by the Energy

Research Institute at Nanyang Technological University. These groups have been engaging with a number of experts from universities, research institutions and companies and comparing results among different numerical codes.

A group of member countries – Japan, India, China, Korea, France and The Netherlands – have been working together on **OTEC** to assess the potential around the world and discuss the present status and plans for OTEC projects.

OES has been developing efforts on the topic of **international performance evaluation of ocean energy technologies** with strong inputs from the European Commission, the U.S. Department of Energy and from Wave Energy Scotland, aiming to support the

definition of a fully defined set of metrics and success thresholds for wave energy technologies and develop an internationally accepted approach.

In 2018, OES supported the organisation of a second workshop on **ocean energy in insular conditions**, aiming to discuss barriers and opportunities, and also supported a workshop on **open water testing** to exchange information and experience on all aspects of planning, development and operation of open-water test facilities.

The **need to assess the number of jobs related to the development of the ocean energy sector** has been discussed and the terms of reference to prepare this study was prepared, with the work expected to start in 2019.

COUNTRY HIGHLIGHTS IN 2018

AUSTRALIA

- In 2018 Australia created a new hub for marine energy research and innovation, the **Wave Energy Research Centre (WERC)**, collocated in Perth and Albany.
- The industry continues to strengthen as a result of the formation of the **Australian Ocean Energy Group (AOEG)**, a virtual ocean energy cluster that will be formally established in early 2019.
- A new document that may influence future ocean renewable policy in Australia has been commissioned by the Commonwealth Australian Renewable Energy Agency (ARENA). It reviews prospects for the medium- and long-term development of ocean energy in the country.
- A national wave energy resource assessment is available via the Australian Wave Energy Atlas and further a national tidal energy resource assessment is under preparation.
- **MAKO Tidal Turbines** has been successfully testing a turbine at a large Australian port and the company is simultaneously progressing with a demonstration project in South East Asia.
- A number of Australian developers and researchers are engaged in a few well advanced development and research projects on tidal and wave energy: **BOMBORA** is looking to funding opportunities in Europe for its wave energy developments, **Nandy's R&D** has moved through the proof of its wave energy concept, **Wave Swell Energy** is working on funding its 200 kW wave energy project, and **Carnegie** is moving now with the design of CETO 6 wave energy project of 1.5 MW.

BELGIUM

- Several initiatives for the development of the blue economy, including marine energies, are being promoted in the coastal province of West Flanders, Western part of Belgium. In particular, the **West Flanders Development Agency (POM West Flanders)**, responsible for the implementation of the social economic policy in the region, is promoting the development of ocean energy technology by the academic sector and private companies.
- The **Flemish Agency for Innovation and Entrepreneurship (VLAIO)** has been supporting a new 'Innovative Business Network Offshore Energy', and in 2018 a 'Blue Cluster' was set up aimed at large companies & SMEs active in the blue economy sector, including marine energies.
- Belgium has become member of the **Europe Leading Blue Energy (ELBE)** project aiming to position Europe as the world technological and industrial leader in blue energy.
- Ghent University is partner in the European funded project - **MET-CERTIFIED** – dedicated to the development of recognised standards and certification schemes in the sector, and is coordinated by the Dutch Marine Energy Centre.
- **WECANet**, an open pan-European Network for Marine Renewable Energy of 30 countries with a focus on wave energy, was initiated in 2018, coordinated by Ghent University, supporting training, networking and collaboration in Europe.
- **Laminaria**, a Flemish wave energy developer is progressing with a 200 kW prototype to be tested at EMEC in 2019.

CANADA

- In Nova Scotia, the Marine Renewable Energy Act acclaimed into legislation in 2018 will lead to the identification of **Marine Renewable Energy Areas (MREAs)**.
- Several funding programmes were open in 2018 to support clean energy technologies across Canada, although not exclusively dedicated to support ocean energy.
- Two projects have been deployed at Bay of Fundy. **Cape Sharp Tidal** successfully deployed at FORCE tidal site and tested the Open Hydro turbine for the third time, although the company was dissolved very soon after; and Black Rock Tidal Power, renamed as Sustainable Marine Energy Canada (SMEC) successfully deployed the floating platform from Sustainable Marine Energy (UK) without turbines at Grand Passage, for research and environmental monitoring purpose.
- Other active developers in Canada include **Big Moon Power, Mavi, Bluetility and Neptune Small**, all progressing with scaled devices.
- Extensive work in environmental monitoring and resource assessment has been carried out in Nova Scotia and British Columbia.
- A relevant study was published in 2018: a **'State of the Sector Report'** highlighting the opportunities, challenges and path for ocean energy in Canada and globally.

CHINA

- In 2018, a total budget of RMB 79 million was granted for two marine renewable energy demonstration projects.
- A storage desalination offshore floating energy platform using the wave energy technology **'Sharp Eagle'** was installed in the sea in 2018 and successfully connected to the grid on Wanshan Island.
- Sharp Eagle is also being used by Guangzhou Institute of Energy Conversion (GIEC) in a multi-use floating platform; the first prototype started to be constructed in December 2018.
- There are also plans for the deployment of a Sharp Eagle demonstration farm on Wanshan Island, with governmental support; the design has been finished and its manufacture started in December 2018.
- **Zhejiang University** has deployed a third horizontal axis turbine near Zhairuoshan Island with an installed capacity of 600 kW, after the two previous ones of 60 and 120 kW.
- Since March 2018 a new 300 kW horizontal axis turbine deployed by the **Guodian United Power Technology**

Company Limited has been connected to the grid, near Zhairuoshan Island.

- The **LHD Tidal current project**, developed by Hangzhou United Energy Co. Ltd, has now reached an installed capacity of 1.7 MW and has generated more than 1 GWh since August 2016.

DENMARK

- The developments of wave energy projects by Danish developers continue to be stimulated by the **Danish Wave Energy Partnership** involving 11 active Danish developers working together for the development of wave energy through industrial partnerships.
- Eleven Danish wave energy companies are active in the field: **Exowave, WavePiston, Waveplane, Weptos, Floating Power Plant, Leancon, Crestwing, KN Swing, Wave Dragon, Resen and WaveStar**.
- **Crestwing** prototype was deployed in autumn 2018 in the northeast of the islands of Hirsholmene in Frederikshavn Municipality.
- In October 2018, **WEPTOS** in co-operation with AAU completed tests at a sheltered site located in Lillebælt between Jutland and Fyn in Denmark, north of the small island Brandsø.

EUROPEAN COMMISSION

- In March 2018, the **SET-Plan Ocean Energy Implementation Plan** was endorsed with technical, financial and environmental actions for the coming years to support the development of ocean energy technologies towards commercialization and cost-reduction.
- The contribution of Ocean Energy to the blue economy was accounted in the European Commission first **"Annual Report on the Blue Economy"** published in July 2018. The report examines the role of emerging sectors, including ocean energy, and the opportunity that they bring for attracting investments and potential future deployments.
- In the period 2007-2018, a variety of ocean energy projects were supported by the European Commission, for a total investment of €864 million.
- Two new environmental projects - **SEAWAVE** and **WESE** - amounting €1.5 million have been approved, funded by EASME (Executive Agency for Small and Medium-sized Enterprises) and will provide information on the interaction between wave energy converters and the marine environment.
- The European Commission conducted a **"Market Study on Ocean Energy"** assessing financial needs and providing options for the design of Investment Support and Insurance Fund for ocean energy technologies, which was published in 2018.

- The Joint Research Centre (JRC) is doing an inventory of Future Emerging Technologies relevant to energy supply; the type of innovations on ocean energy to bridge the gap with the market have been analysed and are published in the report “**Future emerging technologies for the ocean energy sector: innovation and game-changers**”.
- A public study on the impact of European funded ocean energy R&D projects of the last 20 years is on-going aiming to provide insights into the impacts of funding and opportunities to influence the recommendations to increase future R&D impacts.
- Horizon 2020, the current framework programme to support innovative R&D actions has, since its inception in 2014, provided more than €165 million for ocean energy R&D to 44 different projects. Currently, 17 R&D projects on ocean energy are being funded.
- Three on-going projects - **Marinet2**, **Marinerg-I** and **Foresea** - supported by the European Commission H2020 and European Regional Development Fund (ERDF) offer access to testing infrastructures and centres and to research facilities across Europe.
- Other two new projects - **Marine Energy Alliance** and **Blue-GIFT** - funded by the Interregional European projects (Interreg) fostering transnational cooperation among neighbouring countries were launched in 2018.

FRANCE

- Several prototypes were tested in French waters over 2018, partly thanks to the current availability of four grid-connected test sites (SEM-REV, SEENEOH, Brest-Sainte Anne and Paimpol-Bréhat) and Ushant Island pilot site.
- In 2018, five new R&D projects on marine renewable energies addressing technological bottlenecks and environmental issues were approved through the “Institute for the Energy Transition” call for tenders, in conjunction with France Energies Marines.
- The **SABELLA D10 turbine** was re-installed at the Fromveur Passage connected to the Ushant Island grid (Brittany) in October 2018, for another 3-year testing.
- A new round of testing of the 1/6-scale **Eel Energy tidal turbine** was successfully completed in the Bay of Brest in March 2018.
- Under **PHARES**, project the availability of renewable energy solutions for an insular community of 2000 inhabitants (Ushant Island) will be demonstrated combining two D12 Sabella turbines, a wind turbine, a PV solar plant and a storage capacity, expected to be operational by 2020.

GERMANY

- Around 15 R&D institutes and universities in Germany have been involved into developing wave, tidal current and osmotic power, mainly in the framework of National and European research projects, over the last decade.
- The joint project “TidalPower - Development of a Platform System for Cost Efficient Utilization of Tidal Energy” was concluded in 2018. The project consortium led by **SCHOTTEL HYDRO** delivered the ready-to-build concept of the “TRITON S40”, a semi-submersible large platform with 40 tidal turbines rated at 2.5 MW.
- The Sustainable Marine Energy’s (SME) “PLAT-I” floating platform, has been equipped with four of SCHOTTEL HYDRO’s tidal turbines and rated at 280 kW; it is currently being tested at the Grand Passage in the Bay of Fundy, Canada.
- In 2018, SCHOTTEL HYDRO also delivered a 500 kW power take-off system to the Swedish tidal kite developer Minesto for the “Holyhead Deep” project in Wales, UK.
- **NEMOS** successfully tested its first scaled wave energy model (1:3) in Danish waters, at the Nissum Bredning nearshore test site and has been further progressing with the development of components for its full scale prototype.
- **SINN Power GmbH** plans to deliver four additional wave energy modules to the existing test site at the port of Heraklion, Greece. Two modules were successfully put into operation in July 2018. The company has also been doing feasibility studies on the island of São Vicente, Cape Verde and in West African Guinea.
- Other German suppliers, certification companies and consultants are contributing to the technology and project development in the sector, which shows the technology export opportunities on ocean energy that exist for the German industry.

INDIA

- In 2018, the Indian Government approved the construction of new **OTEC powered desalination plant** in Kavaratti, Lakshadweep Islands. NIOT has been doing research on various OTEC components at its recently established OTEC laboratory.
- The **OWC wave powered navigational buoy** for use in ports, which was installed successfully off Kamarajar Port, Chennai, has been continuously operating for several months. Following the success of this first unit, NIOT is building two more wave powered navigational buoys planned to be deployed at other two ports in India.
- Research on Oscillating Water Column (OWC) principle for wave energy devices and its power take-off continues to be a key research activity at NIOT. Both unidirectional

and bidirectional impulse turbines have been tested at the OWC navigational buoy, in open sea trials for performance comparison and evaluation.

IRELAND

- 2018 saw the completion of the review of the Offshore Renewable Energy Development Plan (OREDPA), confirming that all relevant agencies and Government departments within Ireland remain committed to support offshore renewable energies.
- The department of Communications Climate Action and Environment (DCCAE) issued a public consultation on the design of a new Renewable Electricity Support Scheme (RESS) in Ireland, focused on the design options of the proposed new market scheme. The DCCAE is currently in the process of seeking state aid approval for the scheme and it is anticipated that the first auction call will open in 2019.
- **Galway Bay Quarter Scale test site** was awarded a new 35 year lease this year, which allowed for the test site to be recommissioned in July 2018. Two small devices have been tested in this site: a wave monitoring equipment "Anteia" developed by the Spanish company Zunibal and a small scale wave energy device called eForcis.
- **Ocean Energy** completed the construction of the OEBuoy 500 kW machine in Oregon USA, which will be then transported for Hawaii in 2019 to be tested at the US Navy WETS facility. Prior stages included several deployments at the Galway Bay test site having accumulated over 24,000 hours of open water testing.
- A 25 KW river turbine prototype developed by the Irish company **Gkinetic** was tested in Bordeaux in France.
- Disappointingly, 2018 was also the year that Naval Energies ceased production of the Irish based **OpenHydro tidal technology**, despite successfully deploying a 2MW machine in Canada in July 2018.

ITALY

- **SeaPower scrI**, a non-profit private consortium, spin-off of the University of Naples "Federico II", is developing an innovative tidal current devices, in the Strait of Messina. The company has been also testing a wave energy system called PIVOT system and a full scale prototype will soon be installed on a breakwater in the port of Civitavecchia (Roma).
- The **E-WAVE 100 converter**, a dual-chamber Oscillating Water Column (OWC) device, designed for being integrated into vertical-wall breakwaters, was tested at 1:2 scale in the Large Wave Flume (GWK) of Hannover University, in the context of the MARINET2 EU project.

- Other wave energy devices at an early stage of development include: the **ECOMar system** to be integrated in breakwaters by Kuma Energy, the IMPETUS-UNIPA patented by the University of Palermo, and Seaspoon patented by a spin-off of the Technical University of Genoa.

MEXICO

- **CEMIE-Océano** has been conducting several R&D activities addressing different aspects of ocean energy technology: resource assessment, experimental testing, environmental studies, materials, grid interconnection and energy storage.
- A theoretical assessment of wave, current, salinity gradient and thermal gradient energy resources in Mexico elaborated by CEMIE-Océano is now available.
- Based on numerical modelling evaluations of tidal and ocean current energy, two regions with good resource have been identified: the northern Gulf of California, and the northern Mexican Caribbean, with other possible sites in the Pacific (Baja California).
- Energy from salinity gradient has been investigated by CEMIE-Océano, in particular the RED technique, exploring the use of new membranes.
- A small OWC prototype equipped with a Wells turbine has been in operation since September 2018 in the Bay of Acapulco. CEMIE-Océano has further two projects planned to be installed soon: a wave energy device at Sauzal Port, Baja California, and an ocean current turbine at Cozumel Channel.

2018 saw the completion of the review of the Offshore Renewable Energy Development Plan (OREDPA), confirming that all relevant agencies and Government departments within Ireland remain committed to support offshore renewable energies.

REPUBLIC OF KOREA

- The Government has been supporting the development of a tidal current test site and a wave energy test site. The wave energy test site in the western waters of Jeju Island is planned to be ready by 2019, managed by Korea Research Institute of Ships and Ocean Engineering (KRISO) and will have a total capacity of 5 MW connected to the grid; one berth makes use of the existing **Yongsoo OWC plant**, with other 4 berths in shallow and deep waters.
- The **floating pendulum wave energy converter (FPWEC)**, developed by KRISO, with 300 kW capacity, was connected to one of the berths, at 40 m water depth, in 2018.
- KRISO has also been investigating small wave energy converters of the oscillating water column (OWC) type integrated in breakwaters combined with an energy storage system and connected to a micro grid.
- OTEC is also a key research area at KRISO, which has been progressing with plans to install a **1 MW OTEC demonstration plant** on a barge in the eastern coast of Korea by 2019.
- KIOST has been working on the development of an **active controlled tidal current project**, which resulted in the fabrication of a 200 kW turbine in 2018.
- In 2018, Korea started a new international cooperation project with China for knowledge exchange on ocean energy that will run until 2020. As part of this project, the first China-Korea Symposium on Marine Energy was held at Zhejiang University.

THE NETHERLANDS

- During 2018, **SeaCurrent** validated a tidal kite technology for moderate speeds at the test facilities of MARIN and is planning to install a first commercial demonstration project in the Wadden Sea, north of the Netherlands.
- After testing the salinity gradient technology at the pilot facility on the Afsluitdijk, **Redstack** now aims at a first demonstration plant in Katwijk (near The Hague).
- **Tocado** has been tested their 1.25 MW tidal current plant in the Eastern Scheldt and the company is now planning a 2 MW successor, consisting of 5 turbines.
- OTEC development in the Netherlands continues steadily. The collaboration between private enterprise and academia is strong and evidenced through the activities made by technology developers and the Delft University of Technology (TU Delft). In 2018, the OTEC company **Bluerise** has completed a private round of funding and has secured commitment for a development loan from the Dutch Development Bank (FMO) for a SWAC/OTEC project in Jamaica. In 2018, the TU Delft started offering a PhD and MSc course on

OTEC and continues to host Bluerise's OTEC prototype. Aruba and Curacao (Caribbean islands within the Dutch Kingdom) released public policy documents highlighting a priority of development of SWAC and OTEC technologies.

NEW ZEALAND

- **NZ-based Energy Hydraulics (EHL)**, in partnership with US-based NWEI, conducted a second deployment of the Azura Wave device at the US Navy's Wave Energy Test Site in Hawaii during 2018. This was a continuation of the testing conducted during 2015-17, incorporating new design changes.
- This partnership has secured a further US\$4 million of grant funding from the US DOE to support the development of a full scale commercial device. This funding is contingent on a further US\$4 million of matched funding, which is currently being sought from sources including the NZ Government.

NORWAY

- **Runde Environmental Centre (REC)**, located on Runde Island on the Norwegian west coast for wave energy testing, has now a 3 km/0.5 MW sea cable to shore with grid connection.
- REC has been used by the Swedish developer Waves4Power currently undergoing long term grid connected testing with its 100 kW wave energy device.
- **Fred Olsen** is undergoing a second round of tests at the US Navy's Wave Energy Test Site (WETS) on Hawaii, with the BOLT Lifesaver wave energy device to power an oceanographic sensor package.
- **Ocean Power** has been developing a tidal device using a Darieus-turbine of 300 kW to be installed in Lofoten.

PORTUGAL

- In 2018, WavEC, IST, INEGI, University of Algarve, Kymaner and other Portuguese Universities, public and private entities were active partners in national or international research efforts on ocean energy.
- In 2018, the results of the call **Blue Fund** aiming to fund research and development projects on demonstration prototypes for wave energy systems and/or components was announced: 6 projects were approved for wave energy demonstration projects and robotic equipment for operations in the sea.
- There has been continuous progress with the oscillating water column and air turbines, following decades of research in Portugal with this type of wave energy technology and its power take-off. A **new biradial self-rectifying air turbine** with a new type of fixed guide vanes designed by IST and supplied by the Portuguese

company **Kymaner** has been tested in one of the OWCs of the Mutriku breakwater and later on a floating OWC prototype in the Basque country, at BiMEP.

- The European H2020 funded project **WETFEET**, coordinated by WavEC, came to an end in 2018; within this project, a multipurpose platform made of OWCs wave energy converters have been tested by IST at Plymouth University.
- A new floating wave energy converter - **UGENT** - with an interior U-shaped oscillating water column and a self-rectifying air turbine has been developed at IST, and a scale model was tested at the wave tank of Plymouth University, within the European project MARINET 2.
- At University of Algarve there is one active group on tidal current energy projects, the Marine Offshore Renewable Energy (MORE) team, which has been involved in the testing of a small scale tidal current turbine Evopod E1 developed by the UK developer Oceanflow Energy.
- The Institute of Science and Innovation in Mechanical and Industrial Engineering (INEGI) started to develop a marine buoy prototype integrating a new solution for harvesting energy based on triboelectric nanogenerators.
- **AW-Energy** has granted funding from the EU Horizon2020 programme (MegaRoller project) for development of a Power Take-Off unit for a 1MW device. This R&D project started in May 2018 and will run until 2021, with a total of €5 million funding, with two Portuguese partners.
- **Pico Wave Power Plant**, at Azores, was disconnected from the network on April 2018 after ten years of testing, during which it made a very valuable contribution to the promotion of wave energy research, development and innovation.

SINGAPORE

- In Singapore there is an active support for hosting demonstration projects on marine energies; ocean energy has been identified as a relevant alternative for islands and remote coastal areas.
- The **Sentosa Tidal Test Site** developed with public funding aims to be a showcase for tidal energy providing opportunities to develop local technologies.
- MAKO Tidal Turbines in collaboration with Energy Research Institute @ Nanyang Technological University (ERI@N) has been developing a demonstration project on Sentosa Island.
- The offshore renewable energy integration and demonstration (Offshore REIDS) project, also termed as **Tropical Marine Energy Centre (TMEC)**, has been initiated by ERI@N and financially funded by the ClassNK firm (a Japanese classification society) and seeks to pave the way for establishing a scaled marine energy testing facility for tropical waters.

- There is now much focus on the development of guidelines and standards to support the local supply chain and to investigate technologies and a methodology for meeting energy needs on remote islands.

SPAIN

- The Basque Energy Agency (EVE) launched in 2018 a new call of its “Demonstration and validation of emerging marine renewable energy technologies” programme with a budget of €2.5 million for 3-year duration projects.
- **OPERA** project, funded under the H2020 programme and coordinated by TECNALIA, continues making good progress. 2018 saw the finalization of the bi-radial turbine tests at Mutriku Wave Power Plant and the implementation of that turbine in the MARMOK-A-5 device at BiMEP test site. A sophisticated new type of mooring rope – elastomeric mooring tethers- was successfully deployed marking a significant new milestone for this project.
- **MARMOK-A-5** device developed by OCEANTEC (acquired by IDOM in September 2018), after surviving two winters, and refitted to integrate new innovations, was re-installed at BiMEP.
- **Mutriku breakwater** in the Basque Country, based on the OWC (Oscillating Water Column) technology, reached some 1.77 GWh since 2011.
- **WEP+**, Ocean ERANET Cofund project, is a wave energy demonstration project based on the Wedge technology, which has accumulated roughly 4 years of testing at PLOCAN on the Canary Islands.
- **Wedge Global** has also been developing SMARTWEC Project, aiming at optimizing wave energy converters point absorber type by increasing offshore reliability and energy output.
- Under the European funded project **LifeDemoWave**, a wave energy prototype has been tested in Galicia with two different PTO, 25 kW each.
- Galicia-based **Magallanes Renovables** has been tested its 2 MW floating platform for tidal energy at EMEC in Scotland.

SWEDEN

- **Minesto** has been developing a technology called Deep Green that can produce electricity from low-velocity tidal and ocean currents and in 2018 successfully installed and commissioned a 500 kW demonstrator at Holyhead Deep off North Wales.
- **CorPower** completed a half scale demonstration of their wave energy device in EMEC, and is progressing now to the next stage involving full scale devices.
- In 2018, a new phase of the Swedish Energy Agency’s national ocean energy programme was started. The

activities and priorities of the programme are guided by the Swedish Energy Agency's strategy for research and support to ocean energy which was finalised in 2017 and is available on the website¹. The programme will run from 2018-2024 and has a total budget of around €10.2 million. A first call for proposals has been held and decisions on which projects to fund are being finalised.

- In 2018, a 3-years R&D project aiming to develop a dynamic low voltage cable was ended. This project was a collaboration between developers, research organisations and supplier, with funding from the Swedish Energy Agency.

UNITED KINGDOM

- A new report issued in 2018 by ORE Catapult's '**Tidal stream and wave energy cost reduction and industrial benefit**' highlights the significant potential economic and employment benefits from ocean energy to the UK.
- To date, the UK has invested an estimated £508 million of private funds into the development of ocean energy technology. This has been supported by £70 million of direct public support to technology developers, part of £300 million of wider public support (including academia and test centres). To inform budget setting for 2019 onwards the UK Government has convened the Energy Innovation Needs Assessment (EINA) process. This coordination activity will bring together UK Government funding agencies from across the UK to prioritise and allocate R&D investment between the low-carbon technologies, including ocean energy.
- The Scottish Government continues to support the ocean energy sector including on-going funding of **Wave Energy Scotland**. Through targeted innovation projects and research activities, several new funding awards were made in 2018.
- **Marine Energy Wales** is guiding the creation of a successful ocean energy industry in Wales with the sea testing infrastructures under development. Skills and innovation are being supported by the Marine Centre Wales, which opened in 2018 with £2.8 million funding.
- In Northern Ireland, the Marine Renewables Industry Association (MRIA) published in late 2018 the '**Discussion Paper on the Marine Spatial Planning Needs of the Marine Renewables Emerging Technologies**' to support the development of a Marine Plan.
- **Tidal stream projects** made significant strides in demonstrating performance and reliability:
 - SIMEC Atlantis Energy's **MeyGen array project** in Scotland's Pentland Firth surpassed 10 GWh of generation onto the grid by December 2018. The next phase, planned for late 2019, is to install an additional two Atlantis turbines updated to 2 MW each.

- The **Nova Innovation** three-turbine 0.3 MW array has continued to operate and further granted an extension to their existing seabed lease to increase capacity from 500 kW to 2 MW. This extension will enable the installation of three additional turbines, each rated at 100 kW, thus increasing the number of turbines in the water from three to six.

- **Orbital Marine Power** continued testing their 2 MW twin rotor floating tidal turbine at the site and in 12 months of continuous operation achieved 3 GWh of generation. The company will design and build their optimised production model, for deployment at EMEC in 2020.

- The Swedish tidal developer Minesto built and deployed their commercial scale DeepGreen500 tidal kite off Holyhead, North Wales. Other tidal current projects are further planned to be tested next years at EMEC and include the Instream Energy Systems's 100 kW floating tidal device with funding from Innovate UK's Industrial Strategy Challenge Fund, the Magallanes Renovables's 2 MW floating tidal device and the Tocardo floating platform intended to provide a generic solution for the integration of tidal turbines.

- **Wave energy projects** are progressing in UK waters:

- Wello Oy marked its first year of deployment of Penguin at EMEC's Billia Croo test site and the next generation of the device is planned be relocated to EMEC, next to the existing one, after testing in Estonia.
- CorPower deployed their half-scale C3 device and demonstrated 18 months of combined dry and ocean testing at EMEC.
- Marine Power Systems (MPS) built their 10 kW WaveSub device in Pembroke Dock and are currently finalising tests in FaBTest, Cornwall.
- The Australian wave energy developer Bombora Wavepower secured a £10.3 million ERDF grant to test a 1.5 MW prototype at Pembrokeshire.
- Laminaria's 200 kW LAMWEC device is planned to be deployed at EMEC in 2019.

THE UNITED STATES

- The U.S. Department of Energy's **Water Power Technologies Office (WPTO)** has maintained an upward trend since 2013, and in 2018 the annual budget was at \$105 million, a 25% increase from 2017 and its highest level ever.

¹ <http://www.energimyndigheten.se/nyhetsarkiv/2017/energimyndigheten-antar-strategi-for-havsenergi/>

The U.S. Department of Energy's Water Power Technologies Office (WPTO) has maintained an upward trend since 2013, and in 2018 the annual budget was at \$105 million, a 25% increase from 2017 and its highest level ever.

- The **Naval Facilities Engineering (NAVFAC)** is funding and actively managing the Navy's Wave Energy Test Site (WETS) in Hawaii with a budget of \$35 million to support Alternative and Renewable Energy R&D.
- In April 2018, a recent funding opportunity was announced of up to \$23 million to support marine energy technologies.
- In June 2018, the **six awardees selected** to receive a total of \$6.7 million in federal funding have been announced: The Igiugig Village Council (IVC) in Alaska, Ocean Renewable Power Company, Resolute Marine Energy, Oscilla Power, Enorasy and the University of Alaska.
- During 2018, WPTO collected public comments on its draft report "**Potential Maritime Markets for Marine and Hydrokinetic Technologies**" that details economic and technical landscapes of 14 different non grid markets for marine energy technologies. The final report will be released in 2019.
- Several teams have been engaged in developing innovative products and systems with improvements on control or cost reduction: The ocean energy research team at NREL conceived and patented an innovative wave converter concept; SNL completed wave tank testing work in advanced wave energy dynamics and controls.
- On environmental issues, two relevant initiatives are pointed out: (1) the new sensor package, NoiseSpotter, developed by a research group from Integral Consulting, Inc. in collaboration with PNNL, designed to record sound generated by marine energy devices and (2) the Living Bridge Project, led by the University of New Hampshire, where the Memorial Bridge has been converted into a demonstration "smart bridge" equipped with environmental sensors powered by a 25 kW cross-flow vertical axis tidal turbine supplied by New Energy Corporation of Calgary, Alberta.
- The 1 MW OE Buoy developed by **Ocean Energy USA** (originally from Ireland) has been under construction in Oregon and once complete will be towed to the **U.S. Navy's WETS** in Hawaii for testing. The BOLT Lifesaver wave energy device from the Norwegian company Fred Olsen was also redeployed in this testing facility.
- **Ocean Power Technologies (OPT)** signed an agreement with Enel Green Power to evaluate developing a project in Chile; the company has a contract to supply the Oil & Gas company, Premier Oil, with one of its PowerBuoy systems, targeting a deployment date in the summer of 2019.
- **Columbia Power Technologies (C-Power)** completed the testing of its novel direct-drive PTO at NREL that will be installed in 2019 at the StingRAY open water demonstration project at WETS.
- Northwest Energy Innovations (NWEI) redeployed their full scale system Azura™ at WETS in February 2018.
- **Verdant Power** Fifth Generation Kinetic Hydropower System (Gen5 KHPS) is working on the optimization of cost effective installation, operation, maintenance, and retrieval.
- **Ocean Renewable Power Company (ORPC)** in partnership with Igiugig Village of Alaska is developing the RivGen Power System, a submerged cross-flow river current turbine system planned to be deployed in 2019, an example of the application of ocean energy to remote locations.
- **Oscilla Power** has done extensive testing at scale and is aiming to test their system in the second half of 2019 at WETS in Hawaii.
- Both **AquaHarmonics** and **CalWave**, first and second-place winners of the 2016 Wave Energy Prize respectively, have been advancing their designs.

OPEN SEA TEST SITES

There are many open sea test sites established across the world and each has its own challenges, such as consenting issues, resource and operating environments. Test centres also provide very different service offerings to industry.

The development of open sea testing facilities encourages ocean energy development by enabling practical experience of installation, operation, maintenance and decommissioning activities for prototypes and farms, as well as on services and streamlining procedures.

CANADA

TEST SITE NAME	LOCATION
Fundy Ocean Research Centre for Energy (FORCE)	Minas Passage, Bay of Fundy, Nova Scotia
Canadian Hydrokinetic Turbine Test Centre (CHTTC)	Winnipeg River, Manitoba
Wave Energy Research Centre (WERC)	Lord's Cove, Newfoundland & Labrador

USA

TEST SITE NAME	LOCATION
U.S. Navy Wave Energy Test Site	Kaneohe Bay
Pacific Marine Energy Center PacWave North Site	Newport, Oregon
Pacific Marine Energy Center PacWave South Site	Newport, Oregon
Pacific Marine Energy Center Lake Washington	Seattle, Washington
Pacific Marine Energy Center Tanana River Hydrokinetic Test Site	Nenana, Alaska
Jennette's Pier Wave Energy Test Facility	Jennette's Pier, North Carolina
U.S. Army Corps of Engineers (USACE) Field Research Facility (FRF)	Duck, North Carolina
Center for Ocean Renewable Energy	Durham, New Hampshire
UMaine Offshore Intermediate Scale Test Site	Castine, Maine
UMaine Deepwater Offshore Renewable Energy Test Site	Monhegan Island, Maine
OTEC Test Site	Keahole Point, HI
Marine Renewable Energy Collaborative (MRECo) Bourne Tidal Test Site (BTTS)	Bourne, Massachusetts
Southeast National Renewable Energy Center - Ocean Current Test Facility	Boca Raton, Florida

NETHERLANDS

TEST SITE NAME	LOCATION
Oosterschelde	Eastern Scheldt barrier
Tidal Test Centre (TTC)	Den Oever
BlueTec floating platform	Texel Island
REDstack	Afsluitdijk

UNITED KINGDOM

TEST SITE NAME	LOCATION
European Marine Energy Centre (EMEC)	EMEC Orkney, Scotland
Wave Hub	Wave Hub Cornwall, England
FaBTest	Falmouth Bay in Cornwall
Marine Energy Test Area (META)	Milford Haven Waterway in Pembrokeshire
Morlais Tidal Demonstration Zone	West Anglesey

IRELAND

TEST SITE NAME	LOCATION
Galway Bay Marine and Renewable Energy Test Site	Galway Bay
AMETS	Belmullet, Co. Mayo

PORTUGAL

TEST SITE NAME	LOCATION
Pilot Zone	Viana do Castelo
Aguçadora test site	Aguçadora

SPAIN

TEST SITE NAME	LOCATION
BiMEP	Basque Country
Mutriku Wave Power Plant	Basque Country
Oceanic Platform of the Canary Islands (PLOCAN)	Canary Islands

MEXICO

TEST SITE NAME	LOCATION
Port El Sauzal	Ensenada, Baja California
Station Puerto Morelos	Puerto Morelos, Quintana Roo

DENMARK

TEST SITE NAME	LOCATION
DanWEC	Hanstholm
DanWEC NB	Nissum Bredning

SWEDEN

TEST SITE NAME	LOCATION
The Lysekil wave energy research test site	Lysekil
Söderfors research site	Dalälven

BELGIUM

TEST SITE NAME	LOCATION
Ostend wave energy test site	Harbour of Ostend

NORWAY

TEST SITE NAME	LOCATION
Runde Environmental Centre (REC)	Runde Island

CHINA

TEST SITE NAME	LOCATION
National small scale test site	Weihai, Shandong Province
Zhoushan tidal energy full scale test site	Zhoushan, Zhejiang Province
Wanshan wave energy full scale test site	Wanshan, Guangdong Province

REPUBLIC OF KOREA

TEST SITE NAME	LOCATION
K-WETEC (Korea Wave Energy Test and Evaluation Centre)	Jeju
Korea Tidal Current Energy Centre (KTEC)	Undecided

FRANCE

TEST SITE NAME	LOCATION
SEM-REV, wave and floating offshore wind test-site	Le Croisic
SENEOH estuarine and 1/4 scale tidal site	Bordeaux
Paimpol-Brehat, tidal site	Bréhat

SINGAPORE







TEST SITE NAME	LOCATION
Sentosa Tidal Test Site	Sentosa island

01

OVERVIEW OF OES

The Ocean Energy Systems Technology Collaboration Programme (OES) is an intergovernmental collaboration between countries, to advance research, development and demonstration of technologies to harness energy from all forms of ocean renewable resources for electricity generation, as well as for other uses, such as desalination, through international co-operation and information exchange.

THE OES EMBRACE THE FULL RANGE OF OCEAN ENERGY TECHNOLOGIES:

-  **Waves**, created by the action of wind passing over the surface of the ocean;
-  **Tidal Range** (tidal rise and fall), derived from the gravitational forces of the Earth-Moon-Sun system;
-  **Tidal Currents**, water flow resulting from the filling and emptying of coastal regions as a result of the tidal rise and fall;
-  **Ocean Currents**, derived from wind-driven and thermohaline ocean circulation;
-  **Ocean Thermal Energy Conversion (OTEC)**, derived from temperature differences between solar energy stored as heat in upper ocean layers and colder seawater, generally below 1000 m;
-  **Salinity Gradients**, derived from salinity differences between fresh and ocean water at river mouths.

Offshore wind, marine biomass or submarine geothermal which occupy sea space but do not directly utilize the properties of seawater, are not included in the OES remit.

Most ocean energy technologies are being developed to produce electricity, although some of them are being developed to deliver other or multiple products, derived from the physical and chemical properties of seawater (e.g. fresh water and sea water air conditioning).

VISION, ROLE AND VALUES



VISION

As the authoritative international voice on ocean energy we collaborate internationally to accelerate the viability, uptake and acceptance of ocean energy systems in an environmentally acceptable manner.



ROLE

Using its unique position as an intergovernmental organisation, the OES's role is to:



Connect with organisations and individuals working in the ocean energy sector to accelerate development and enhance economic and environmental outcomes;



Educate people globally on the nature of ocean energy systems, the current status on development and deployment, and the beneficial impacts of such systems, improve skills and enhance research;



Motivate governments, agencies, corporate and individuals to become involved with the development and deployment of ocean energy systems;



Facilitate research, development and deployment of ocean energy systems in a manner that is beneficial for the environment and provides an economic return for those involved.

ORGANISATION VALUES

The OES also established a set of Organisational Values that would guide its future actions:

Integrity: Any information provided can be relied upon.

Outcome-oriented: We are driven by pragmatic solutions that enhance the global community.

Knowledgeable: All information is based on fact and we strive to ensure that we always have the most relevant and up-to-date researched facts available.

Inspirational: Our performance and our members are committed to providing inspired and collaborative information to accelerate the implementation of environmentally friendly ocean energy systems globally.

Collegial: We are committed to working professionally with each other in the pursuit of our audacious goal.

Surrounding the OES Vision, and being influenced by the organisational values of OES and its brand values, the Strategic Plan for 2012 - 2016 identified and prioritised four Critical Success Factors, for which an action plan this term has been prepared:

- High quality information
- A strong communications programme
- An effective organisation
- Shared capability growth

THE VISION FOR OCEAN ENERGY

“Ocean Energy is recognised as being a respected and critical source of green energy. The diversity of devices available is fit for purpose and kind to the environment in which they operate. The capacity provided facilitates security of supply for nations and a commercial return for the supplier. As a green energy of choice, Ocean Energy is recognised for its contribution to economic growth.”

THE VISION OF OES

“As the Authoritative International Voice for Ocean Energy we collaborate internationally to accelerate the viability, uptake and acceptance of ocean energy systems in an environmentally acceptable manner.”

OES BRAND VALUES

Trusted Independent Source
Substantiated knowledge
Inspiring Action
We care for society and the environment
Collaborative Sharing

OES ORGANISATIONAL VALUES

Integrity
Outcome Oriented
Knowledgeable
Inspirational
Collegial

CRITICAL SUCCESS

FACTOR 1:
High Quality
Information

CRITICAL SUCCESS

FACTOR 2:
A Strong and Effective
Communication Capability

CRITICAL SUCCESS

FACTOR 3:
An Effective
Organisation

CRITICAL SUCCESS

FACTOR 4:
Shared Capability
Growth

MEMBERSHIP

The Technology Collaboration Programme on Ocean Energy Systems (OES) was initiated by three countries in 2001 and has been growing steadily. As of December 2018, 24 Member Countries and the European Commission are active members of the OES.

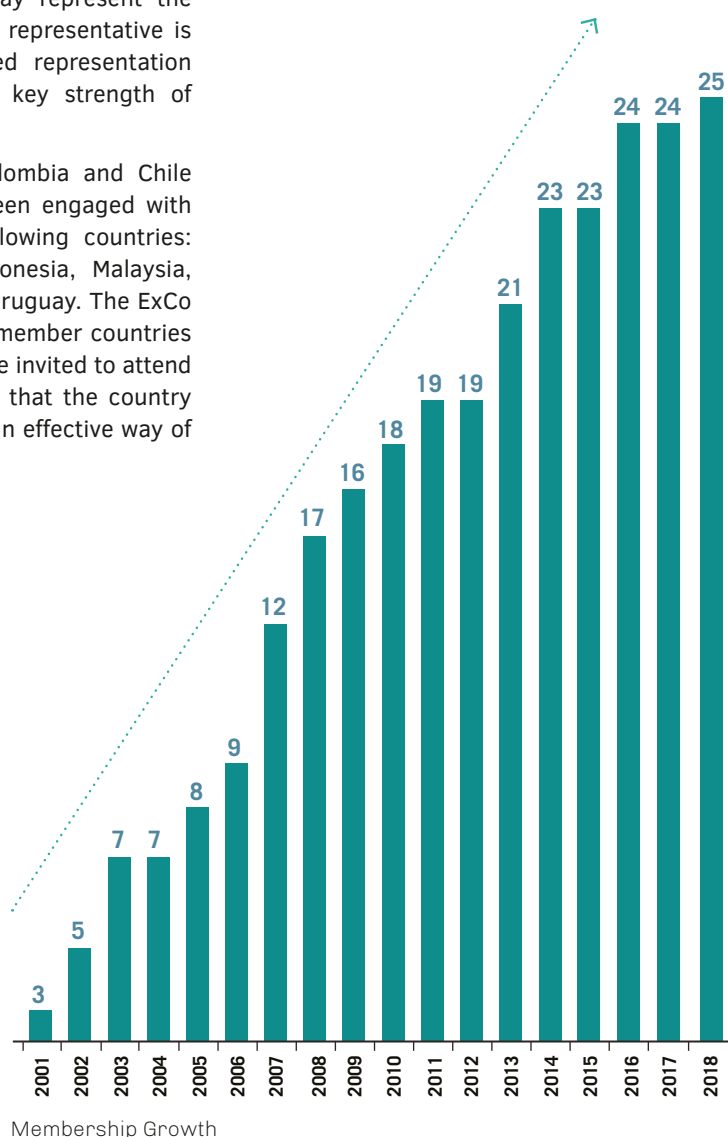
After several years of hiatus, Australia has issued its intent to reinstate membership of the OES. This has been made possible via the Australian Renewable Energy Agency (ARENA) International Engagement Program. The Australian Government nominated the Commonwealth Scientific and Industrial Research Organisation (CSIRO), an independent federal Government funded agency responsible for scientific and industrial research, to join OES on their behalf. The Implementing Agreement was signed on 6 August 2018.

National governments appoint a Contracting Party to represent the country in the Executive Committee (ExCo). The Contracting Party can be a government ministry or agency, a research institute or university, an industry association or even a private company. Governments also nominate alternates, who may represent the government at ExCo meetings, if the nominated representative is unavailable. Consequently, there is a diversified representation of interests in the ExCo, which is seen as a key strength of the organization.

The responses to the formal invitations to Colombia and Chile were still pending at year end. OES has also been engaged with governments or key representatives of the following countries: Argentina, Brazil, Finland, Ghana, Greece, Indonesia, Malaysia, Malta, Mauritius, Panama, Peru, Philippines and Uruguay. The ExCo has adopted a practice of encouraging potential member countries to send observers to ExCo meetings. Observers are invited to attend up to three meetings, after which it is expected that the country will commit to joining the ExCo. This has proven an effective way of encouraging membership.

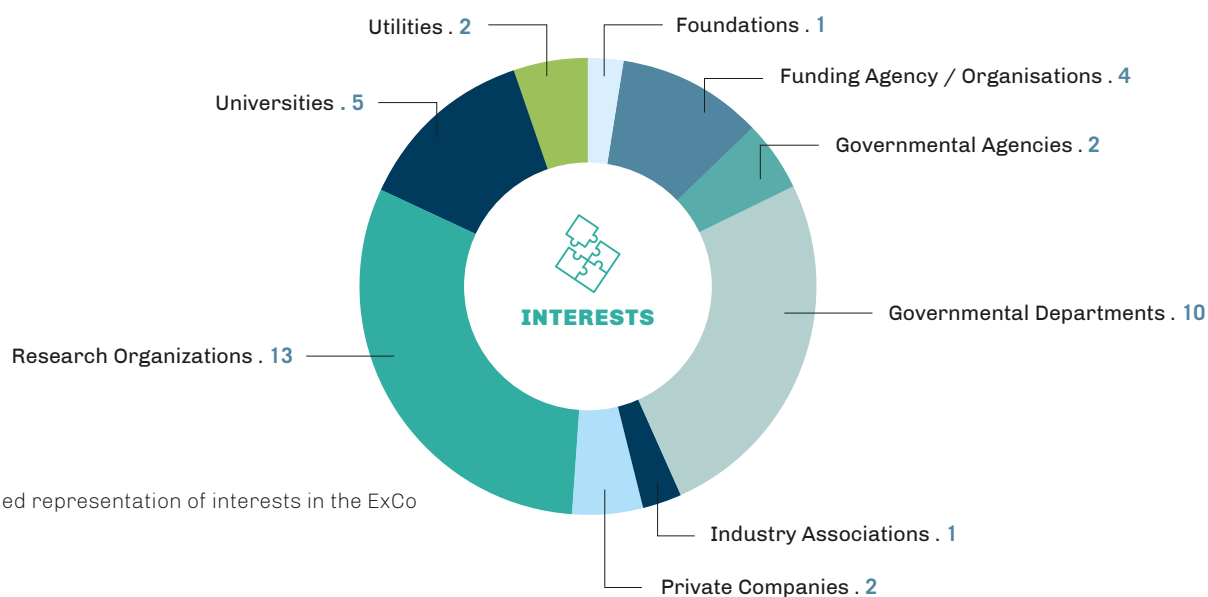
MEMBER COUNTRIES

Belgium	Mexico
Canada	Monaco
China	Netherlands
Denmark	New Zealand
European Commission	Norway
France	Portugal
Germany	Singapore
India	South Africa
Ireland	Spain
Italy	Sweden
Japan	UK
Republic of Korea	USA



Contracting Parties

YEAR OF SIGNATURE	COUNTRY	CONTRACTING PARTY
2001	Portugal	Laboratório Nacional de Energia e Geologia (LNEG)
	Denmark	Ministry of Transport and Energy, Danish Energy Authority
	United Kingdom	Department of Energy and Climate Change (DECC)
2002	Japan	Saga University
	Ireland	Sustainable Energy Authority of Ireland (SEAI)
2003	Canada	Natural Resources Canada
2005	United States of America	United States Department of Energy (DOE)
2006	Belgium	Federal Public Service Economy
2007	Germany	The Government of the Federal Republic of Germany
	Norway	The Research Council of Norway
	Mexico	The Government of Mexico
2008	Spain	Biscay Marine Energy Platform - BiMEP
	Italy	Gestore dei Servizi Energetici (GSE)
	New Zealand	Aotearoa Wave and Tidal Energy Association (AWATEA)
	Sweden	Swedish Energy Agency
2010	Republic of Korea	Ministry of Oceans and Fisheries
	South Africa	South African National Energy Development Institute (SANEDI)
2011	China	National Ocean Technology Centre (NOTC)
2013	Nigeria (non-active member)	Nigerian Institute for Oceanography and Marine Research
	Monaco	Government of the Principality of Monaco
2014	Singapore	Nanyang Technological University
	The Netherlands	Netherlands Enterprise Agency
2016	India	National Ocean Technology Institute (NIOT)
	France	France Energies Marines
	European Commission	European Commission
2018	Australia	Commonwealth Scientific and Industrial Research Organisation (CSIRO)



EXECUTIVE COMMITTEE

The overall programme is headed by an Executive Committee (ExCo) composed of representatives from each participating country and organisation.

A list of the members of the ExCo is shown in Appendix 1. The ExCo meets twice a year and takes decisions on the management, participation and implementation aspects of the OES.

The 34th ExCo meeting took place in Cherbourg, France, on 14-15 June with 20 Delegates and 2 Observers (Chile and Australia). The 35th ExCo meeting was held in Las Palmas at Gran Canaria, on 29 - 30 November with the participation of 18 Delegates.

Contracting Parties pay an annual membership fee to the Agreement Common Fund, which covers administrative expenses, including the secretariat services, communication and dissemination activities and sponsorship activities and collaboration with other international organisations. The common fund may also support coordination of ongoing R&D projects, launch of new projects, organisation of OES workshops on prioritised topics and commissioning of studies or reports. It does not cover R&D activities; research should be funded by participants involved in a specific task. The annual membership subscription fee is € 7000.

The ExCo elects a Chairman and two Vice-Chairs, who serve for a 2-year term. Together with the Secretary, the Chairman and Vice-Chairs form the Cabinet, which manages the day-to-day decision-making to implement the annual Work Programme. The ExCo Secretariat is based in Lisbon, Portugal and is run by WavEC Offshore Renewables.



34th ExCo Meeting in Cherbourg, France (14 – 15 June 2018)



35th ExCo Meeting in Las Palmas, Gran Canaria, Spain (29 - 30 November 2018)

In 2018, Henry Jeffrey (United Kingdom) served as Chair and Annie Dallman (USA) and Yann-Hervé De Roeck (France) served as Vice-Chairs. At the last ExCo meeting, Henry Jeffrey was re-elected for a second 2-year period (2019 – 2020).

In 2018, OES participated in two IEA events:

- Joint Workshop of the IEA Renewable Energy and Energy Efficiency Working Parties held in Paris, France on 29 March 2018.
- 74th IEA Renewable Energy Working Party Meeting (REWP 74) held in Rome, Italy, on 24-26 October 2018.

WORK PROGRAMME

The primary activity of the OES is to develop research projects (Tasks) to study various aspects of ocean energy systems. Each research project (Task) is managed by an Operating Agent who is selected by the Executive Committee.

The Tasks running in 2018 are presented below, as well as those activities under discussion that could potentially turn into future Tasks. OES has an internal prioritisation process for selection of activities which includes the analysis of the following points: how it fits with the OES Strategic Plan, the impact in member countries, the impact of the work and the relevance of the work being done by the OES. In many cases, before initiating a new project, the OES supports the organisation of workshops on a specific topic as a way to discuss the role that OES can play, as well as the format of the collaborative work.

Oes Work Programme – Current, completed and future tasks

TASK N°	TITLE	LEAD BY	STATUS
1	Review, Exchange and Dissemination of Information on Ocean Energy Systems	Portugal	Active
2	Development of Recommended Practices for Testing and Evaluating Ocean Energy Systems	Denmark	Completed
3	Integration of Ocean Energy Plants into Distribution and Transmission Electrical Grids	Canada	Completed
4	Assessment of Environmental Effects and Monitoring Efforts for Ocean Wave, Tidal and Current Energy Systems	United States	Active
5	The Exchange and Assessment of Ocean Energy Device Project Information and Experience	United States	Completed
6	Worldwide Web GIS Database for Ocean Energy	Germany	Active
7	Cost of Energy Assessment for Wave, Tidal, and OTEC at an International Level	UK	Active
8	Consenting Processes for Ocean Energy on OES Member Countries	Portugal	Active
9	International Ocean Energy Technology Roadmap	UK	Active
10	Wave Energy Converters Modelling Verification and Validation	Denmark	Active
11	Investigation and Evaluation of OTEC Resource	Japan	Active
12	Stage Gate Metrics International Framework for Ocean Energy	European Commission	Active
13	Tidal Energy Converters Modelling Verification and Validation	Singapore	Active
14	Assessment of Jobs Creation on Ocean Energy (Terms of Reference under preparation)		New activities under discussion
15	Ocean Energy in Insular Conditions		
16	Open Water Testing		

02

ACHIEVEMENTS IN 2018

COLLECTION OF INFORMATION AND DISSEMINATION

Task 1 aims at communicating about the main findings of the OES programme through the most adequate communication channels.

The following main types of communication actions have been conducted throughout the year:

- **OES website** (www.ocean-energy-systems.org), the primary source of promoting OES activities; it includes a restricted area for the ExCo Delegates with information to be discussed at each ExCo meeting and repository of all presentations in meetings.
- **Social Networks:** news are promoted through a LinkedIn group and a twitter account with more than 800 followers by the end of 2018.
- **Annual Report**, the flagship document of the OES and a marker for industry development. It includes detailed information from Member Countries. A subdomain was created on the website with an interactive online version: <http://report2018.ocean-energy-systems.org/>
- **Newsletter** issued each semester, after each ExCo meeting, presenting the most up-to-date information exchanged by the Delegates during the meetings: <https://www.ocean-energy-systems.org/news-events/newsletter/>
- **Press Releases:** Six press releases were issued in 2018 announcing the launch of the Annual Report and other publications, the membership of Australia and the host of the next ICOE conference.
- **Presence** of OES representatives in several events related to ocean energy.



NEW PUBLICATION LAUNCHED IN 2018

The brochure Spotlight on Ocean Energy was launched in 2018 providing insights of 20 ocean energy projects and 5 policy initiatives on the OES member countries.

MAIN EVENTS IN 2018 WHERE OES WAS PRESENT

The table below lists the main events in 2018, in which the OES was represented promoting the OES activities. In addition to these conferences, OES is organizing workshops in parallel with ExCo meetings or sponsoring workshops with different focused themes.

OES Participation in International Events during 2018

EVENT	LOCAL	DATE	REPRESENTED BY
Monaco Blue Initiative	UK Edinburgh	April	Chairman
International Conference on Ocean Energy	FRANCE Cherbourg	June	Chairman
Marine Renewable Asia Summit 2018	INDONESIA Jakarta	August	Vice-Chair
Australian Ocean Renewable Energy Symposium	AUSTRALIA Perth	November	Chairman
World Ocean Council Sustainable Ocean Summit	CHINA Hong Kong	November	Chinese Delegate

CLOSE LINK WITH ICOE



ICOE conferences are held every two years and focus on the industrial development of ocean energy. In 2018, ICOE was held in Cherbourg, Normandy, from June 12th to 14th in La Cité de la Mer (<http://icoe2018normandy.eu/>).

Past ICOE conferences have been held in Germany, France, Spain, Ireland, Canada and UK. The International Steering Committee of ICOE includes the Chairman of the OES. Further, several OES Delegates are also members of the Steering Committee.

In particular, the OES keeps past ICOE conference material on a dedicated website managed by OES (www.icoe-conference.com), providing the historical archive of all papers from previous ICOE conferences. All presentations at ICOE 2018 have been uploaded on this site.

The OES is also the organiser and supporter of a “student poster award” for the best posters at the ICOE conferences; in 2018 three researchers received a cash prize.



COLLABORATION WITH INORE



INORE is a network for postgraduate researchers working with issues related to offshore renewable energy. The OES encourages this network and provides annual financial sponsorship for specific activities conducted by INORE, particularly to develop membership in new regions, including Asia and the Pacific.

Part of the annual sponsorship from OES is usually allocated to the Blue Energy Collaborative Scholarships (BECS). The OES-BECS grant, up to an amount of €1000 per awarded project, funds travel expenses

and accommodation at the research institutions where the collaborative work will take place. In addition to providing an opportunity for international work, the OES-BECS grant also seeks to foster advances in the field of ocean energy through publication of research results and journal papers, making the results of the work available to a wider audience.

In 2018, the OES sponsored two Blue Energy Collaborative Scholarships and also the participation of INORE in two workshops (Taiwan/China and Chile).

COLLABORATION WITH IEC-TC 114

International Electrotechnical Commission (IEC) Technical Committee (TC) 114, Marine Energy – Wave and Tidal Energy Converters: OES has a formal liaison with this technical committee to develop international standards for wave and tidal energy technologies.

Dr Purnima Jaliha, Delegate from India, has been nominated as the expert to coordinate, in particular, the collaboration with the working group “PT 62600-20 - General guidance for design and analysis of an Ocean

Thermal Energy Conversion (OTEC) plant”, on behalf of the OES. Further, a number of ExCo members serve as project leaders or participants in some of the TC114 working groups. Some OES tasks can provide technical information for future standards.

In 2018, the IEC Chairman, Jonathan Colby, was invited to give an overview of the IEC standards work in one of the ExCo meetings and discuss with the ExCo the benefits of a collaboration among both organisations.

ASSESSMENT OF ENVIRONMENTAL EFFECTS AND MONITORING EFFORTS

PROJECT DURATION

Phase III: 2016 - 2020

Phase II: 2013 - 2016

Phase I: 2010 - 2013

COORDINATOR

Samantha Eaves, US Department of Energy (DOE)
/Allegheny Science & Technology

PARTNERS

Bureau of Ocean Energy Management (US)
National Oceanic and Atmospheric Administration (US)

TECHNICAL CONSULTANTS

Pacific Northwest National Laboratory (US), assisted by
Aquaterra Ltd (UK)

PARTICIPATING COUNTRIES

Australia, Canada, China, Denmark, France, India, Ireland,
Japan, Norway, Portugal, South Africa, Spain, Sweden,
United Kingdom and United States of America

FURTHER INFORMATION

<http://tethys.pnnl.gov/>

OBJECTIVES

This project seeks to be the premier international program engaged in bringing together information and practitioners on environmental effects of marine renewable energy (MRE) development.

The third phase of Annex IV was approved by the OES ExCo in May 2016. This phase builds on the work completed during the first two phases by continuing to collect, synthesize, and disseminate information on environmental effects and by providing access to such knowledge and information related to research, monitoring, and evaluation of environmental effects of MRE information that helps advance the MRE industry. Annex IV is supported by the publicly accessible, online knowledge management system Tethys, developed by Pacific Northwest National Laboratory. Tethys was created to provide a commons for Annex IV and to facilitate connectivity and collaboration among members of the MRE community. Tethys hosts a knowledge base and map viewer providing access to MRE documents, archived webinars, and other media that are focused on important scientific issues critical to the siting and permitting (consenting) of MRE devices worldwide. Annex IV also plays a role in supporting the dissemination of information via international conferences and events, as well as focusing on new environmental research and data on interactions among marine animals, habitats,

and MRE devices. Annex IV is characterized by the close involvement of an analyst from each of the 15 member nations. Each analyst was nominated by his/her nation and is committed to contributing 20 hours per quarter to Annex IV.

MEMBER NATION ANALYSTS

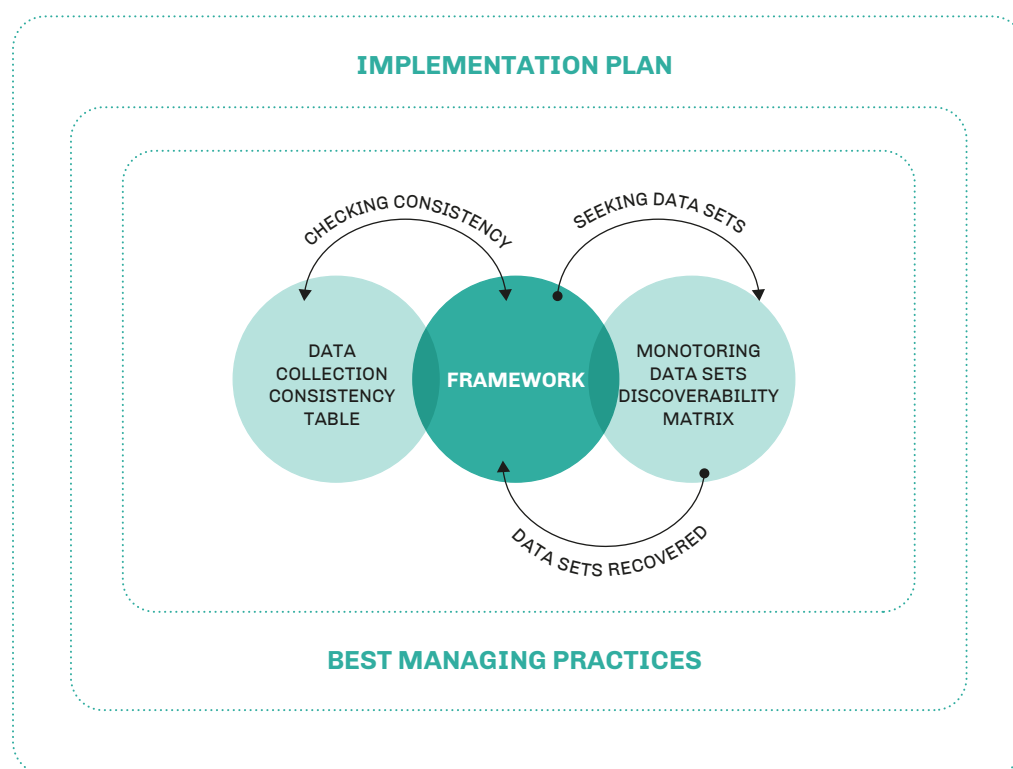
Key tasks asked of each analyst include:

- Reporting progress in MRE development and environmental effects work within their respective countries, updating existing Annex IV metadata forms, and providing new ones as projects or research studies are initiated;
- Acting as an expert to help identify topics for Annex IV webinars, expert forums, and workshop topics;
- Providing reviews of Annex IV products and Tethys content;
- Acting as an ambassador for Annex IV in their respective country;
- Translating key Annex IV documents from English into the official language of their respective country.

THE ROAD TO RETIRING ENVIRONMENTAL RISKS

During 2018 Annex IV pursued a process for retiring, or putting aside, environmental risks that continue to slow consenting and hamper MRE development. Regulators around the world continue to require that a significant amount of data be collected to determine the effects of devices and systems on marine animals, habitats, and ecosystems. The collection of pre- and post-installation monitoring data places substantial cost burdens on device and project developers, threatening the financial viability of this young industry. The risk retirement process is made up of three parts: 1) Data Transferability and Data Collection Consistency; 2) Risk Retirement Pathway; and 3) Outreach and Engagement with the MRE Community.

Data Transferability and Data Collection Consistency - A process has been developed to systematically collect, classify, and enhance discoverability of datasets from already consented projects. These datasets will be made accessible to regulators, developers, and other stakeholders. The purpose of these datasets is to provide lessons learned from consented projects to simplify and reduce the need for extensive data collection on new consenting and licensing applications. As part of classifying datasets, there is a need to ensure that environmental data are collected in a consistent manner for future applications. The process is shown graphically (Figure 5).



Data Transferability Framework (Framework) is made up of: 1) Data Collection Consistency Table which provides preferred measurement methods or processes, reporting units, and the most common methods of analysis or interpretation/use of data; 2) Monitoring Data Sets Discoverability Matrix which allows a practitioner to discover data sets that meet the criteria presented in the Framework; 3) Best Management Practices includes five BMPs related to data transferability and collection consistency; and 4) Implementation Plan which is the approach for implementing the Framework and BMPs.

Risk Retirement Pathway

A draft risk retirement pathway has been developed and shared with the Annex IV analysts. The pathway describes the necessary steps to retire a specific risk, which includes “offramps” that allow the risk to be put aside as not likely to cause harm to marine animals or their environment. The process can be applied to any specific environmental risk such as collision risk with turbine blades, effects of underwater noise on animals, electromagnetic fields, etc. Application of this pathway will be explored in greater detail in the 2020 State of the Science Report.

Outreach and Engagement with the MRE Community

Following the survey of US regulators carried out in 2017, several additional Annex IV countries have surveyed their national regulators. The purpose of the surveys is to understand which risks from MRE development the regulators feel are most important, to guide tailored outreach programs to ensure regulators are familiar with existing scientific information, and to determine the most appropriate methods for engaging them in discussions of risk retirement and requests for monitoring data that are proportional to risks. During 2018, a substantial program of outreach and engagement was carried out with US regulators through a series of in person and online

meetings that demonstrated the state of knowledge for key environmental risks of importance to US regulators (collision risk, underwater noise, EMF, habitat changes, and changes to physical systems such as circulation and sediment transport). During each meeting, regulators were asked to assess the state of knowledge as it applied to their jurisdictions and to discuss what additional data or analysis they might need to move forward. The regulators were also introduced to the data transferability process, asked for input, and encouraged to explore the work further. In particular, the regulators were enthusiastic about the development of the dataset discoverability matrix (Fig.5) that would allow them to access, categorize, and apply datasets from consented projects. The same process will be carried out in other Annex IV countries as the results of the regulator surveys become available. A workshop on the data transferability process will engage the international community in September 2019.

DISSEMINATION OF INFORMATION ON ENVIRONMENTAL EFFECTS

Tethys, the online knowledge management system which supports Annex IV material, continues to expand and increase user interactions. The publicly available collection of scientific papers, reports, and other media

increased by 681 papers in the last year, for a total of 4,723 entries. The collection includes information on offshore wind effects as well, but a large portion of the papers are exclusively about marine energy development. Over the past year, Tethys has been visited by 53,926 users, viewing 129,984 pages (note these numbers often represent users who visit multiple times). During 2018, a peer review process was completed for Tethys by soliciting reviews and feedback on the content and functionality of Tethys from the greater Tethys community online. A total of 119 reviews were collected. Respondents rated the value that they derive from using Tethys as an 8.2 on a scale of 1 to 10. The results of the peer review help understand how users interact with the website and provide a guide to improvements and changes to the system.

WORKSHOPS AND CONFERENCES

During 2018, Annex IV hosted two workshops. The first was held in April in conjunction with the Environmental Interactions of Marine Renewables (EIMR) conference in Orkney, UK on social and economic data needed to address consenting. This was a follow on workshop from one held around the European Wave and Tidal Energy Conference (EWTEC) in 2017. Approximately 30 participants came together to examine case studies of social and economic issues surrounding consenting of MRE projects in Europe and North America. The output of the two workshops led to development of a document on best management practices for tracking social and economic data, and a Short Science Summary on the topic (<https://tethys.pnnl.gov/socio-econ>).

The second workshop was held in conjunction with the International Conference on Ocean Energy (ICOE) in Cherbourg France in June 2018, focused on the data transferability and data collection consistency processes. Over 20 people from seven countries participated. The output of the workshop included a short workshop report, as well as providing important guidance and examples for the data transferability process.

Papers were presented at a number of conferences in 2018 that focused on Annex IV work including papers on data transferability at EIMR (April 2018), Marine Energy Technology Symposium (METS) in Washington DC in May, at ICOE (June 2018), and at AWTEC (September 2018). An extended paper on the 2016 State of the Science report findings was also presented at AWTEC.

WEBINARS

Three webinars were hosted by Annex IV during 2018. The first focused on direct outreach for Tethys, ensuring that new users understood the resource as well as introducing new features to more experienced users 49

people attended in person and 387 have downloaded the presentation since. The second webinar Optimizing Permitting for MRE through Data Transferability, was held September 25th, and reported on the work that Annex IV has been doing on regulator outreach over the year. 37 people attended and 173 have downloaded the presentation since. In addition, Annex IV sponsored a webinar: Using Underwater Video to Monitor Fish Around Ocean and River Energy Devices in July 2018 that 47 people attended, and 245 downloaded later. Webinar presentations are archived at: <http://tethys.pnnl.gov/mhk-environmental-webinars>.

COLLECTION AND UPDATE OF METADATA

The purpose of the metadata forms is to ensure that the sum of environmental monitoring data from all deployments anywhere in the world is captured and added to the global knowledge of MRE environmental effects. Building on the collection of metadata from phases 1 and 2, Annex IV has continued to collect and update information on new wave and tidal projects as well as ongoing research studies. Existing metadata forms are updated by working with the country analysts, developers, researchers. There are a total of 158 metadata forms on Tethys; of those 64 are considered to be active projects while the rest represent short term deployments with no follow up or projects that have been withdrawn. Six new project forms were added during 2018. All metadata forms can be found on Tethys under the Knowledge Base.

PREPARING FOR THE 2020 STATE OF THE SCIENCE

The major output of Annex IV Phase 3 will be the 2020 State of the Science report. Preparations for the report began in late 2018 with discussions over a report outline and chapter authorship with the Annex IV analysts.

FUTURE ACTIVITIES

Future efforts for Phase 3 will focus on developing the 2020 State of the Science report and completing the process of risk retirement. A workshop is planned around EWTEC 2019 in Naples Italy to test retirement of two stressors (underwater sound effects and electromagnetic fields). A workshop is also planned for Scotland in February 2019 to further the strategic research agenda towards retiring collision risk with turbines. Annex IV expects to have a presence at several conferences including: METS (Marine Energy Technology Symposium) in the US in April 2019 and EWTEC in Naples in September 2019.

CHANGES TO ANNEX IV BRANDING

Beginning in early 2019, Annex IV will be rebranded as OES-Environmental, to more closely reflect the international ties to OES.

WORLDWIDE WEB GIS DATABASE FOR OCEAN ENERGY

COORDINATOR

Jochen Bard, Fraunhofer Institute IEE, Germany

PARTICIPATING COUNTRIES

All Member Countries

FURTHER INFORMATION

<https://www.ocean-energy-systems.org/ocean-energy-in-the-world/gis-map/>

The goal of this project is to develop and keep updated an interactive web-based GIS mapping application to give interested website visitors access to detailed global information related to ocean energy in an easy to use yet visually striking way.

The available information comprises ocean energy facilities, resources, relevant infrastructure and relevant general geopolitical and geographical information, in conjunction with the respective location and distribution on a global map.

The user of the application can display any combination of the provided information with the help of a point-and-click interface which runs in any common web browser without the need of installing separate software. Through the interface, the viewer can either search for distinctive items or freely zoom and move through the map, select items and display related information and download or print images of the displayed information, as desired.



COST OF ENERGY ASSESSMENT FOR WAVE, TIDAL AND OTEC AT AN INTERNATIONAL LEVEL

PROJECT DURATION

Phase II: 2018 - 2019

Phase I: 2015 - 2016

COORDINATOR

José Luis Villate, Tecnalia, Spain

PARTNERS

The University of Edinburgh, UK

Julia F. Chozas Consulting Engineer, Denmark

RAMBOLL Group A/S, Denmark

NREL, USA

Inn2Grid, Spain

Acadia University, Canada

ADVISORY BOARD

Joint Research Centre of the European Commission

OBJECTIVE

In 2018, a new study on the Levelized Cost of Energy (LCOE) for ocean energy devices was initiated, in continuation of a previous one done in 2015.

In 2015, the study identified the need for homogenization of cost and performance (Capex, Opex, capacity factor and availability) data among different developers and countries. The study showed that whilst progress has been made, the rate at which cost reduction and technology deployment have taken place was below expectations in the sector.

In order to monitor the evolution of ocean energy costs and to assess the impact of different drivers on the LCOE, it was proposed a continuation of this task taking into account historical trends, future development and differences among technologies and countries.

The objective of this second phase of the study was to provide information on the cost of ocean energy based on the methodology and results of the previous study, identifying different technologies, baseline projects in different countries and, when possible, comparing regions and technologies throughout a transparent methodology. The information received from technology developers and project promoters is expected to provide cost targets for different ocean energy technologies. Moreover, targets per cost component (CAPEX, OPEX and capacity factor) are planned to be proposed out using a reverse LCOE approach. Three main aspects will be considered in the evaluation of the cost of energy:

- 1) Use of transparent assumption and methodologies and of accurate data;
- 2) Analysis of historical trends and identification of key cost drivers;
- 3) Use of models to define future projections.

ACHIEVEMENTS

In 2018, a proper questionnaire was developed to collect detailed information from the ocean energy technologies. Real cost and operational data were collected from a number of developers and data collection and analysis was harmonised at national level. Representative baseline projects were developed allowing for comparison based on local cost differences and resources availability. This process aims at delivering anonymised information for each country while taking into account local resources and costs.

The final outcomes of this work are expected to be published in 2019.

WAVE ENERGY CONVERTERS

MODELLING VERIFICATION AND VALIDATION

COORDINATOR

Kim Nielsen, Ramboll, Denmark

PARTICIPATING COUNTRIES

Canada, China, Denmark, France, Ireland, Republic of Korea, The Netherlands, Norway, Portugal, Spain, Sweden, UK and USA

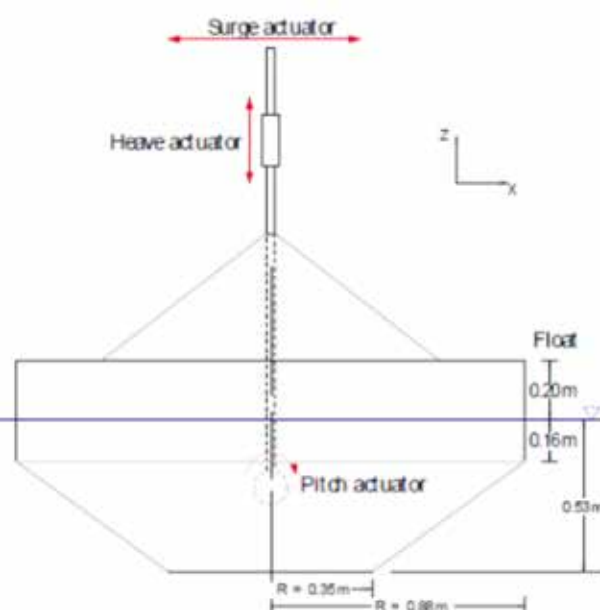
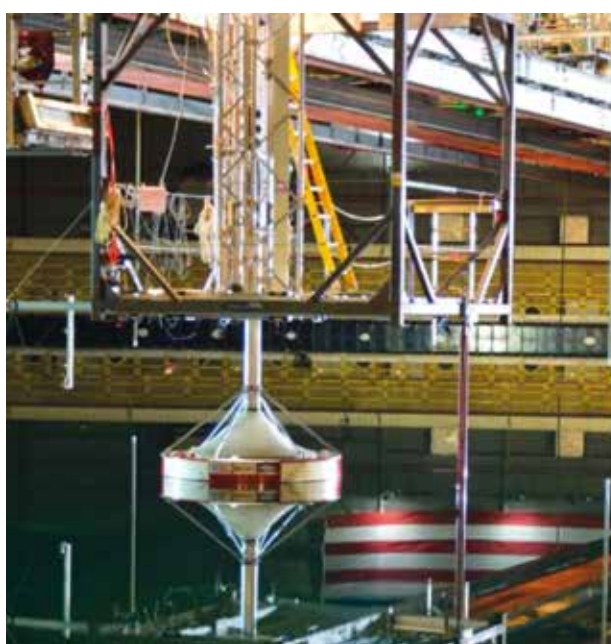
OBJECTIVE

This project aims to verify and validate numerical models used in the design of wave energy converters and power production calculations, with the following long-term goals:

1. To assess the accuracy and establish confidence in the use of numerical models;
2. To validate existing computational modelling tools;
3. To identify uncertainties related to simulation methodologies;
4. To define future research and develop methods of verifying and validating the different types of numerical models.

ACHIEVEMENTS

The first test case used in this project was a Wave Energy Converter based on a heaving sphere concept. The team involved in this task simulated different numerical experiments, such as heave decay tests and power production calculations in regular and irregular wave cases. The simulation results were discussed and published in the EWTEC publication. The second phase of this work, conducted in 2018, consisted in including experimental test data from a heaving, surface piercing wave energy system that was tested at the US Navy MASK basin in 2016, during a test campaign led by Sandia National Laboratories.



Heaving, surface piercing wave energy concept tested at the US Navy MASK and used as a test case for numerical modelling validation

Numerical modelling studies were done for 4 types of tests (decay test, radiation tests, diffraction tests and regular waves tests).

During 2018, two webinars were organised, on 16-05-2018 and 08-11-2018, to discuss results.

The results of the work done were presented at the

3rd International Conference on Renewable Energies Offshore, held on 8-10 October 2018, in Lisbon. The focus of the presentation was on the power performance results from the Sphere as well as comparing simulations to theory. An abstract for a next paper has been submitted to the special edition of the **Journal of Marine Science & Engineering**.

Countries and institutions present in the webinars on numerical modelling for wave energy (2018)

COUNTRY	ORGANIZATION	WEBINAR MAY 2018	WEBINAR NOV 2018
Denmark	Ramboll	x	x
	Aalborg University	x	x
	Floating Power Plant	x	x
	DTU	x	x
France	INNOSEA	x	x
Ireland	Maynooth University	x	x
Japan	Saga University	x	x
Norway	EDRMedeso	x	
Portugal	Instituto Superior Técnico		x
Republic of Korea	KRISO	x	
Spain	Tecnalia	x	x
Sweden	Chalmers University	x	
UK	Wave Venture	x	x
	Plymouth University	x	
USA	NREL	x	x

OCEAN THERMAL ENERGY CONVERSION

COORDINATORS

Yasuyuki Ikegami, Saga University, Japan
Purnima Jalihal, NIOT, India

PARTICIPATING COUNTRIES

China, India, Japan, Korea, France and The Netherlands.

OBJECTIVE

The overall work is carried out by two groups addressing the following topics:

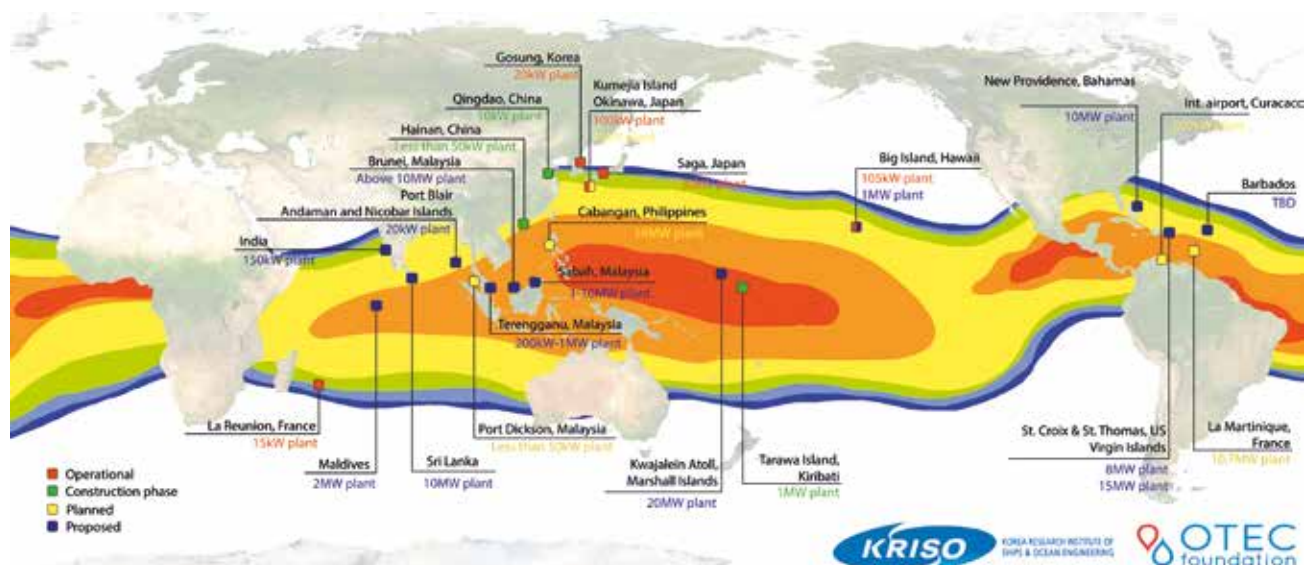
1. Estimation of OTEC potential around the globe (lead by China);
2. Present status and plans of OTEC projects (lead by Korea).

A state-of-the-art report of OTEC activities and projects around the globe has been prepared as a first step to further define a full work programme under this task. The identification of plans and new developments on OTEC in the various regions of the world would be important for

the development of a future roadmap which is one of the goals of this Task.

ACHIEVEMENTS

A second webinar was held on 9 November 2018, organised by the Indian Delegate, Dr Purnima Jalihal, with other 7 participants from France, Japan, Republic of Korea, and two invitees from UK and from a private company in France. In this webinar, participants discussed on how to take the task forward and issues that should be addressed by the group. There was a consensus on the importance of promoting and disseminating knowledge on OTEC to the general public. There are a few recent progresses: KRISO in the Republic of Korea has been working on the development of a 1 MW OTEC plant and Saga University is working with Malaysia on building a new OTEC plant. The outcomes of these projects can generate outputs that are important to be disseminated to the public. A white paper on the advantages of OTEC is planned to be prepared in 2019.



OTEC power plants

PERFORMANCE METRICS INTERNATIONAL FRAMEWORK FOR OCEAN ENERGY

COORDINATOR

Matthijs Soede, European Commission

PARTICIPATING COUNTRIES

All Member Countries

BACKGROUND

A more rigorous technical review approach for the ocean energy sector has been recognised to be important at this stage, making use of improved evaluation methods and metrics that are currently applied in due diligence review and evaluation of ocean energy technologies. Considering the experience and lessons learned for more than two decades of ocean energy technology and market development, a detailed monitoring of progress and success should have the following characteristics:

- Need to differentiate among the various needs of the development stages from R&D, Prototype, Demonstration, to Pre-Commercial and Industrial Roll-out;
- Need to define specific criteria to each development stage;
- A connection must be made between the performance criteria and the availability of certain types of support in the form of public and private funding;
- The process should use continued feasibility checks on the OE technology potential with an increasing focus on LCOE as the technology matures.

After an initial period of focusing on the technological feasibility where the only metric used was the successful technology evolution to higher TRL levels, economics and other social acceptance criteria have been identified to be considered at an early development stage for ocean energy technology.

OBJECTIVE

The objective of this task is to build clarity, information and understanding to support the definition of a fully defined set of metrics and success thresholds for wave energy technologies. These “stage gate measurements of success” in interrelated topic areas are linked to a top-level optimisation of Levelized Cost of Energy (LCOE) – the key metric into which all others inevitably feed. This provides a significant international challenge since a final definition of metrics and success thresholds will, to some extent, be specific to a technology area and perhaps to the type of market targeted.

An internationally accepted approach provides device developers, national and international funding organizations, and the development community the following benefits:

- The ability to measure technology development progress and success;
- A methodology to assist in the management of competitive innovation calls that can compare the viability of competing technologies;
- An approach for ensuring appropriate allocation of funding to the most promising technologies;
- A set of metrics to measure technology progress to illustrate the impact of funding;
- An internationally accepted and credible marker of success to aid in building technology confidence in investors and other stakeholders;
- The ability to make cross technology funding comparisons to help avoid replication or repetition of funding of technologies by numerous funders with similar objectives;
- Decision making assistance for private and public funders.

International collaboration in the development of tools such as metrics creates value through the facilitation of cross-funder comparisons and benchmarking. Common agreement of the method for assessing technologies and the associated success thresholds allow various funding organisations to learn from others, compare programmes, and avoid repetition and replication. This way the international collaboration encourages collaboration among developers and funders and fosters standardisation of processes and designs.

ACHIEVEMENTS

This task is built on the methods and ongoing performance metrics processes for wave energy technology being developed mainly in UK by the Wave Energy Scotland and in USA by NREL. In 2018, OES organised a workshop to assess the current practices and usage of technology performance metrics for ocean energy and to discuss an approach for developing an internationally accepted set of performance metrics for ocean energy development.

TIDAL ENERGY CONVERTERS MODELLING VERIFICATION AND VALIDATION

COORDINATOR

Srikanth Narasimalu, Singapore

PARTICIPATING COUNTRIES

Canada, China, France, India, New Zealand, Sweden and UK

BACKGROUND

There are many modelling tools developed in recent years for ocean energy resource representation at a macro level. However, there is still lack of common understanding on the detailed assessment of tidal renewable energy resources at a macro and micro level at specific sites. Such information about the energy potential and the practical extractable energy is important towards major decision for site selection.

OBJECTIVE

This task aims to develop a common effort to provide useful guidelines for tidal resource mapping through identifying the present practices and compare the

various computational tools for resource mapping. One of the main goals of this task is to prepare a Tidal Energy Resource Modelling Guideline report through the study of the various factors affecting the result of the tidal energy resource prediction simulations towards a numerical code-to-code comparison.

ACHIEVEMENTS

An international network of tidal resource mapping experts has been set up to discuss and identify a common methodology and work towards creating a standard report for modelling in harnessing tidal energy.

Two webinars were organised and hosted by Energy Research Institute @ NTU (ERI@N), Singapore on 14 May 2018 and 9 November 2018. In each event there were ca. 20 attendees from various international tidal energy working teams from all over the world. Participants discussed the different models used for numerical code-to-code comparisons for tidal resource modelling at regional scale as well as site-specific scale.

Countries and institutions present in the webinars on numerical modelling for tidal energy (2018)

COUNTRY	ORGANISATION
Canada	Acadia University
China	Dalian University of Technology
France	LUSAC / Caen University
India	National Institute of Ocean Technology (NIOT)
New Zealand	National Institute of Water and Atmospheric Research
Singapore	Energy Research Institute @ NTU
Sweden	University of Gothenburg
UK	Swansea University
	School of Ocean Sciences, Bangor University
	Imperial College London

ASSESSMENT OF JOBS CREATION ON OCEAN ENERGY

Various roadmaps have advanced figures for jobs creation by the ocean energy sector for the 2025, 2030 and even 2050 horizons, but in the time since, numerous ocean energy technologies have been designed and tested, and even implemented in pilot farms, and it is now time to assess an accurate total number of existing jobs directly related to the sector. It is also time to validate an approach to assess jobs creation in the sector and update projections for the 2030/2050 horizons.

In 2018, the Terms of Reference for this study have been prepared by the OES aiming to estimate job creation in OES member countries based on a combination of surveys and economic models exploiting finely tuned models based on the necessary preliminary field data collected from polling. The proposed project will aim to provide both a methodology and actual figures of job creations with an indication of the accuracy around the outputs.

OCEAN ENERGY IN INSULAR CONDITIONS

The OES has been discussing the use of ocean energy on islands and remote communities where energy is not often affordable, reliable or accessible, and in most cases is imported. These regions have often an abundant ocean energy resource; however introducing ocean energy technology in such environments is a challenge and an opportunity.

A first workshop on “Ocean Energy in Insular Conditions” was organised in 2017, at the Nanyang Technological University (NTU), in Singapore, to facilitate the discussions of the various stakeholders situated on islands or remote coastal areas, with a focus on the small communities of Southwest Asia regions.

In 2018, a second workshop was organised by the Oceanic Platform of the Canary Islands (PLOCAN), in Cherbourg, France. This workshop looked at the opportunities and barriers to local adoption of ocean renewable energy on island communities extending the previous exercise done at Southwest Asia to the Atlantic and Pacific regions. New business models that could support the uptake of

ocean energy in insular regions and remote areas were discussed. This workshop was attended by the European Commission representatives from DG MARE and DG RTD, representatives from the US Department of Energy, developers active on island regions, and experts from universities, R&D institutes and trade associations. The workshop addressed 3 sessions:

- Achievements of ocean renewables on island regions: dedicated to present past and ongoing activities on islands;
- Challenges and opportunities for ocean renewables on island regions: focused on future ocean energy activities on islands planned by developers, challenges and new business models;
- Round table on barriers for the adoption of ocean energy on islands, addressing five different aspects: environmental, technical, legal/political, supply-chain, financial/economic.

A third workshop is planned in 2019, in Hawaii.

OPEN WATER TESTING

Open sea test centres have become a common step in developing an ocean energy industry in countries across the world and are a key milestone in the development of an industry in a region: when technology is advanced enough, a country often seeks to develop an open sea test centre to progress it further. This approach is favoured by public funders as it is an efficient use of public funds, and by technology developers for the reasons outlined above. Open sea test centres are key innovation hubs for the marine energy industry and provide many functions which support its development. These include reducing costs for technology developers and streamline testing programmes; breaking down regulatory barriers such as consenting; developing a regional supply-chain; providing a platform for engaging with decisions makers, investors, media etc.; accelerating knowledge sharing; and many more.

In 2012, OES organised a first workshop in Dublin with open water test site operators and device developers to exchange information and experience on all aspects of planning, development, operation, and usage of open water test facilities. The aim of this workshop was to identify improvements in the capabilities of these facilities for the mutual benefit of the ocean energy industry. Following this initiative, in 2013, the European Marine Energy Centre (EMEC) set up the

International WATERS (Wave and Tidal Energy Research Sites) Network, which provides a forum for open sea tests in the marine energy space to discuss common challenges, explore collaboration opportunities and reduce duplication of efforts and resources.

As a way of enhancing the outputs from the WATERS group and connecting it with the wider development of the sector, in 2018, OES supported the workshop in Taiwan, China organised by EMEC and hosted by the National Taiwan Ocean University.

There are many open sea marine energy test sites established across the world and each has its own challenges, such as consenting issues, resource and operating environments. Test centres also provide very different service offerings to industry. Despite these differences, many are facing the same challenges on a day-to-day basis. The International WATERS network has been an efficient way to share and learn from challenges of other test centres, explore potential collaborations, and discuss how best to meet the needs of industry. The workshop in Taiwan aimed to share updates on progress and challenges from facilities around the world; to identify common test site challenges and opportunities; to provide a forum to discuss key R&D topics; and to identify actions to forge relationships and knowledge transfer among test sites.

Countries and institutions present in the workshop on test sites (TAIWAN, CHINA, SEPTEMBER 2018)

COUNTRY	ORGANISATION
Denmark	Danish Wave Energy Centre (DANWEC)
Ireland	SmartBay Ireland
Japan	JAPAN Class NK Nagasaki Prefecture
Japan	Nagasaki Marine Industry Cluster Promotion Association (NaMICPA)
The Netherlands	Dutch Marine Energy Centre (DMEC)
Republic of Korea	Korea Institute of Ocean Science & Technology (KIOST)
	Korea Research Institute of Ships & Ocean Engineering (KRISO)
Spain	Oceanic Platform of the Canary Islands (PLOCAN)
Taiwan, China	Industrial Technology Research Institute (ITRI)
	National Taiwan Ocean University
UK	European Marine Energy Centre (EMEC)
USA	Hawaii Natural Energy Institute
	National Wind Technology Center

03

INTERNATIONAL CONFERENCE ON OCEAN ENERGY **INTERVIEW**



The International Conference on Ocean Energy (ICOE) is a prestigious international event focused on the industrial development of ocean energy. OES has close link with ICOE.

Held every two years since 2006, ICOE gathers over 500 international stakeholders, experts and exhibitors from the ocean energy sector to discuss device innovation, new market developments and regulatory frameworks to spur commercialization. In addition to unparalleled opportunities to network and learn from industry leaders from around the world, the event provides a variety of forums for attendees to share advancements in research and technology breakthroughs. The purpose of the event is to accelerate development by stimulating collaboration between companies, researchers and development centres. It also targets engagement of operators with experience in related marine and power industry sectors.

OES is the guardian of the ICOE conference and leads a competitive process to select host country teams. Since 2014, the OES has been sponsoring a monetary prize for the three best posters presented at ICOE. The winners of the 2018 edition were:

First prize (€ 1,500): Niño Jhim Andrew Dela Luna (Mapúa University)

Title of the study: Tidal Resource Assessment and Hydrodynamic Simulation of a SeaGen-type Horizontal

Second prize (€ 1,000): Leah Barker Ewart (IDCORE)

Title of the study: Advanced concrete materials for floating wave energy converters

Third prize (€ 500): Lisa Garnier (RTE)

Title of the study: A natural HighTech - the great scallop as a sensor captor

PAST EVENTS

2006 – Bremerhaven, Germany

2008 – Brest, France, hosted by EDF and Ifremer

2010 – Bilbao, Spain, hosted by EVE and Tecnalia

2012 – Dublin, Ireland, hosted by Sustainable Energy Authority of Ireland

2014 – Halifax, Canada, hosted by Marine Renewables Canada

2016 – Edinburgh, Scotland, hosted by Renewable UK

2018 – Cherbourg, France, hosted by the Normandy region

Organised in 2018 by the French company BlueSign in partnership with the Normandy region, ICOE was held in Cherbourg, Normandy, from June 12th to 14th in La Cité de la Mer. In 2018, the National Hydropower Association (NHA) was selected by the OES to host the next conference in 2020 in Washington, D.C. In this chapter, OES interviews the past and future chairs of ICOE.

INTERVIEW WITH: AMANDINE VOLARD

Chair of the ICOE 2018



Environmental engineer, specialized in renewable energies, working now for the French energy agency ADEME and before at the West Normandy Marine Energy that had applied jointly with BlueSign in 2016, to host ICOE in Cherbourg in June 2018.

OES: What was the main motivation of Normandy region to host ICOE 2018?

Normandy has incredible assets for the development of marine energies, and more particularly tidal energy. The Raz Blanchard is only 15NM away from the port of Cherbourg, perfectly suited for the development of marine energy industrial activities. A high capacity grid has been built a couple of years ago and it has the capability to welcome more than 1GW of tidal power. After hosting Seanergy in 2017 in Le Havre, Normandy Region decided to apply to host ICOE2018 with its local partners, the Department of la Manche, the community of Cherbourg and Cherbourg-en-Cotentin, in order to invite the whole ocean energy world to visit the local infrastructures available and to build or maintain international collaborations with businesses and research centers of Normandy.

OES: Did ICOE 2018 met your expectations?

It met our expectations indeed, as more than 3,500 visitors came to the event, over 550 BtoB meetings took place between the 12th and the 14th of June, and over 75 experts took part to the technical visits. The collaboration with the Seanergy event allowed us to broaden the participation and get a large exhibition floor, which was a big asset of the 2018 event. We also managed to include

some conferences that were selected as a whole package, and designed by experts who already knew each other and the would speak on the same topic or project. This required more preparation work but brought sessions that were very clearly designed and had a focused perspective.

OES: What was the main challenge in the organization of such international event?

The coordination of the 140 speakers was definitely a big challenge! But the support from the Executive and Technical Committees were extremely helpful.

OES: How do you think ICOE can benefit the sector?

ICOE is the only international event dedicated to ocean energy. In 2018, we had a good mix of business and academic participants, which made the event even more interesting in terms of innovation and collaboration. Stakeholders of the sector definitely need to collaborate to find creative and competitive ways to design, build, install, operate and maintain ocean energy technologies, in a context where all renewable energies' LCOE keep decreasing and are required to decrease. We believe ICOE2018 is another milestone on the road of ocean energy development, and can't wait for ICOE2020 to see the progress and new challenges of the sector.



INTERVIEW WITH:
LINDA CHURCH CIOCCI
Chair of the ICOE 2020

President and CEO of the National Hydropower Association (NHA), also currently serving on the Board of Directors for the Business Council for Sustainable Energy (BCSE), vice-chair of the Energy and Environment Study Institute (EESI), and founding member of the American Council on Renewable Energy (ACORE).

OES: NHA is hosting ICOE 2020 in Washington, D.C. What does NHA aim to achieve for the international ocean energy industry, for the USA, for the future of ICOE?

Marine energy is the world’s next-gen renewable, and ICOE 2020 is an opportunity to shine a spotlight on its potential as a carbon-free source of energy. For the international ocean energy community, our goal is to make ICOE 2020 the premiere event to showcase device innovation and new market developments. And for U.S. developers, ICOE 2020 creates the ideal platform to learn from industry leaders from around the world and share advancements in research and technology breakthroughs. As countries throughout the world are searching for clean energy

solutions, ocean energy continues to inch closer to commercialization. And not only does marine energy have the potential to power electric grids across the world, it could also support the needs of the blue economy – critical maritime industries and missions such as ocean exploration, national security, or aquaculture. From around the world, stakeholders, experts and exhibitors from the marine energy sectors (tidal, wave, ocean currents, ocean thermal gradients) recognize ICOE as the gold standard event for advancing the industry’s priorities. Our goal at NHA is to continue this tradition, while ensuring the future success of the program.

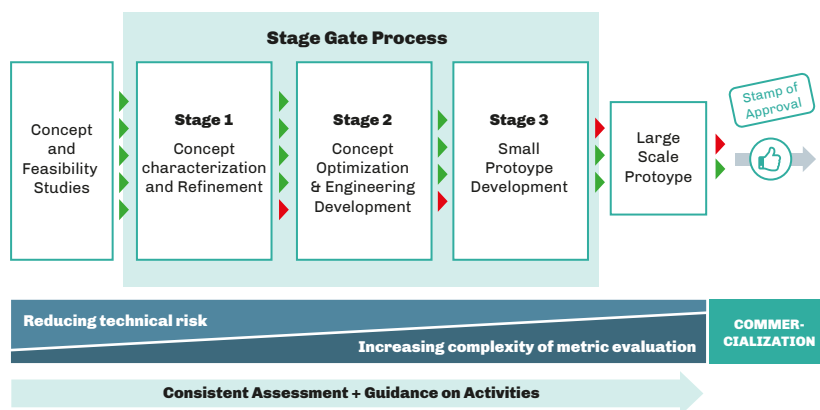
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PERFORMANCE METRICS ON OCEAN ENERGY INTERVIEW

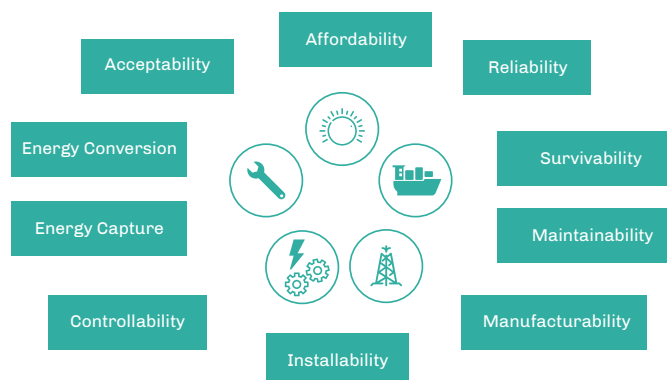
The technology development process, as described by Technology Readiness Levels (TRLs) 1-8, assesses the status of a technology as it progresses from concept to commercial product. As the TRL increases, the technical and financial risk associated with the technology reduces and financial support moves from public funding towards private investment.

Throughout the process, stakeholders need to measure success to support their decision making, whether to allow appropriate award of early stage public funding or to direct private sector investment towards commercially maturing technologies. This can be implemented by applying a Stage-Gated development process where technologies have to pass through gates to reach the next level of funding, thus demonstrating their progress, assessing market feasibility and managing costs, risks and uncertainties. The programmes being run by Wave Energy Scotland (WES) and by the Water Power Technologies Office (WPTO) within the U.S. Department of Energy (DOE), are examples of the application of a Stage Gated process to the Ocean Energy sector.

Stage Gates provide an opportunity to measure the success of the technology and its development. This requires a set of metrics (measures) as well as defined success thresholds (pass-mark). At the early stage of such a programme, concept level technology is assessed against qualitative criteria. As the technology progresses, the assessment must transition to full quantitative detail and the detail of the metrics used to assess this must increase accordingly.



An illustration of the stage gate process



An illustration of the evaluation areas used in the WES stage gate programme

INTERVIEW WITH: LAUREN MORASKI

U.S. Department of Energy (DOE)



Lauren Moraski Ruedy is a Technology Manager in the Water Power Technologies Office at the U.S. Department of Energy. Her focus is on Marine Renewable Energy and she manages research and development projects pertaining to materials development, performance metrics, and in-water device testing. Prior to joining the Department of Energy in 2017, Lauren worked as a civilian Naval Architect for the U.S. Navy at the Naval Surface Warfare Center Carderock Division. Lauren holds a Bachelor of Science in Engineering in Naval Architecture and Marine Engineering from the University of Michigan and a Master of Science in Engineering Management from George Washington University.

OES: The use of a formalized technology evaluation or stage-gate process is in general seen as a promising tool for structured decision-making and controlling project quality. From your experience, what do you consider the major benefits of the application of this process to ocean energy?

LMR: The use of a formalized technology evaluation process as applied to ocean energy has benefits for both technology developers and funding organizations. A formal process enables consistent, fair evaluation of requests for funding; it ensures devices and/or projects are evaluated objectively against the same set of criteria, rather than subjectively against the quality of applications received during a particular round of solicitations. A well done technology evaluation process though should also reflect the logical progression for technology development and use criteria that measures meaningful progress.

OES: How do stage gate processes help the sector to achieve a stamp of approval needed to alleviate investor concerns?

LMR: At the Water Power Technologies Office (WPTO) within the U.S. Department of Energy (DOE), we focus

on funding early-stage research and development efforts whose successes can be measured against an agreed-upon set of metrics; these consistently measured successes will then eventually enable the transition from federal funding to private investment and self-sufficiency. To ensure performance metrics are in alignment with what is used by developers and potential private investors within the sector, DOE issued a Request For Information (RFI) on existing performance metrics within the Marine Renewable Energy (MRE) industry. We focused on four response areas: (1) the performance metrics identified within the document titled “Existing Ocean Energy Performance Metrics” relating to performance in the U.S. marine resource, as well as any additional applications, assumptions, benefits, drawbacks, or other considerations for those metrics, (2) any performance metrics not captured within the “Existing Ocean Energy Performance Metrics” documents, (3) considerations for baseline reference values documenting the current state of the U.S. MRE industry identified by metric and resource type, and (4) feedback specifically on Technology Readiness Level (TRL) definitions as referenced in the document and as those TRL definitions relate to the U.S. MRE industry.

The performance metrics and technology evaluation process not only contributes to decisions made using DOE funding, but also attempts to align MRE performance metrics and evaluation criteria with private investor interests and concerns as well.

The purpose of the RFI was to solicit feedback from industry, academia, research institutions, government agencies, and other stakeholders on the challenges related to assumptions and uncertainties with metrics in the United States that are used to evaluate MRE system and subsystem performance. We were specifically interested in feedback on the application and limitations of those metrics that are currently used or have been used previously, as well as solicited suggestions for new metrics or new applications of existing metrics. Results of the RFI may be used to inform WPTO's strategic planning, contribute to evaluation criteria for potential future funding opportunities, and provide a baseline for U.S. input into international marine renewable energy metrics efforts including the OES Task 12 as well as International Electrotechnical Commission (IEC) Technical Committee (TC) 114, Marine Energy standards. The performance metrics and technology evaluation process not only contributes to decisions made using DOE funding, but also attempts to align MRE performance metrics and evaluation criteria with private investor interests and concerns as well.

OES: Which metrics have DOE/WES used to support its technology development programme and facilitate selection of the most promising technologies for funding?

LMR: When WPTO was first established, Technology Readiness Levels (TRLs) were the primary tool used to evaluate technologies. While this was a reasonable starting point, TRLs do not provide the specific, measurable indicator of progress that performance metrics do. Therefore the program progressed to using various, application-specific, performance metrics for evaluating and monitoring technologies' progress; some examples include LCOE, power to weight ratio, availability, and failure rate. These metrics were developed and vetted

through a series of workshops, beginning in 2015. A more complete list of other metrics DOE has used historically can also be found in the RFI mentioned earlier.

To achieve a more holistic evaluation of a component, device, and/or project, we are now moving in the direction of implementing a suite of metrics for more complete evaluation. This will be accomplished through metrics pairings and incorporating newer performance metrics tools, such as Technology Performance Levels (TPL).

OES: From your experience with performance metrics, what does an international agreement look like on this approach? What can be done to move towards consensus on ocean energy technology evaluation?

LMR: An international agreement on performance metrics, resulting from the work under OES Task 12 for example, would mean incorporation and inclusion of the agreed upon metrics in all future projects and funding opportunities. Adopting and implementing the same metrics would ensure that performance metric values from one country are calculated using data collected in a consistent, repeatable manner resulting in the same performance metric values in another country, and then recognized as such. For example, a device's power capture in country A has the same meaning, value, and calculation methodology in country B, and vice versa. This means developers would not have to collect data and calculate multiple, possibly similar, but different parameters depending on the country in which they intend to test and/or operate. It also simplifies evaluation for investors and funding organizations, since the data available will be consistent and widely applicable. It is for these objectives and the mutually beneficial exchange of knowledge and lessons learned that DOE continues to work closely with Wave Energy Scotland, the European Commission, and the OES delegates to achieve internationally-accepted performance metrics.

INTERVIEW WITH: JONATHAN HODGES

Wave Energy Scotland



Jonathan's engineering career began in the aerospace industry with the development and testing of Rolls-Royce aircraft turbofan engines. In his role as Senior Innovation Engineer at Wave Energy Scotland (WES) he aims to identify opportunities for innovation and then develop appropriate WES funding calls to support the sector towards achievement of cost competitive wave energy technologies. Jonathan is involved in collaboration activities across Europe and the US to develop tools, common metrics for technology assessment and to seek technology transfer opportunities to advance the sector.

OES: The use of a formalized technology evaluation or stage-gate process is in general seen as a promising tool for structured decision-making and controlling project quality. From your experience, what do you consider the major benefits of the application of this process to ocean energy?

JH: In short, it ensures that we fund only the best technologies and therefore accelerate our progress towards commercialisation. What the ocean energy sector needs now is to make most efficient use of public funds, deliver the right research, development and demonstration activity and build the confidence of the private investment community. By using the stage gate process, we create the structure to make this happen. We gain assurance that the most promising technologies receive funding and that technology developers can provide the evidence needed to gain the confidence of potential private investors.

A stage gate process also creates industry-wide visibility of the activities required at each stage and the technology performance expected by stakeholders. The structure of the stage gate process helps ensure that technologies follow a suitable development path with the application of rigorous engineering processes.

We don't want to take shortcuts, we want to reduce risk methodically and move to larger scale and more challenging environments at the right time with the right

technology. A clear, open and fair stage gate process gives us some of the tools needed to do this.

OES: How do stage gate processes help the sector to achieve a stamp of approval needed to alleviate investor concerns?

JH: The stage gate process manages the research and development journey so that it produces the right technologies – the right technologies are those which should achieve that stamp of approval. So really a stage gate process helps to achieve the end goal by assessing the characteristics expected by investors and identifying the technologies that are on track to succeed, providing small stamps of approval on the way.

Importantly, both the development process and the stamps of approval have more effect on investor confidence if everyone agrees with the metrics for success. This means that we need standards and processes as well as the tools to support measurement of the key stage gate metrics. These all need to be recognised through international consensus and widespread use.

International Electrotechnical Committee (IEC) Standards, developed by panels of practitioners from across the world, are growing in number in the ocean energy sector. These provide consistent methods for design and evaluation of aspects such as power performance, testing and measurement of mechanical

loads. Increasingly, these are joined by design protocols produced by the world's verification and certification bodies which, as they continue to develop to meet the needs of the sector, will begin to satisfy the investors' appetite for certainty.

An example of a supporting suite of tools is being produced by DTOceanPlus, a project funded by the European Union's Horizon2020 programme to produce advanced design tools for the selection, development and deployment of ocean energy systems. DTOceanPlus will include a Stage Gate design tool which will facilitate a consistent technology evaluation process using a set of Deployment and Assessment design tools. The project will be completed in 2021 and will be valuable to funders, technology developers and array developers, among other users.

Building confidence in the investment community is a common goal within the ocean energy sector and international collaboration can only bring this sooner.

OES: Which metrics have DOE/WES used to support its technology development programme and facilitate selection of the most promising technologies for funding?

JH: From the beginning, the WES programme has been built around a set of key characteristics that a successful wave energy technology must exhibit. These measures of success (or metrics) form a central part of every stage gate, meaning that technology developers not only receive consistent evaluation as they progress, but also guidance on the content of the R&D programmes, supporting them to deliver those characteristics and be able to demonstrate the results to investors.

Alongside the imperative goals of de-carbonisation and security of supply, most investors are ultimately interested in financial Return on Investment (ROI), so the metrics used to evaluate the candidate technologies must help to identify technologies that will be selected by array developers of the future. The key characteristic that allows a generation technology to achieve this share of the energy mix is affordability, measured by the metric of Levelised Cost of Energy (LCOE). The techno-economic characteristics of a wave energy converter must always be driven by the LCOE target along with the need to be environmentally and socially accepted. The WES programme focusses on the LCOE aspect, which is in turn driven by energy yield, capital cost and operating cost. Stepping down again in this hierarchy, the key technical characteristics which must be evaluated are energy capture & conversion efficiency, reliability and survivability along with more logistical characteristics such as maintainability and installability.

As technology matures through an engineering project, so does the fidelity of design and performance knowledge and the developer's confidence in that knowledge. The metrics used must follow this flow, from early-stage assessment of the fundamentals of a technology concept and its ability to deliver the desired characteristics, right through to objective, quantitative assessment of metrics such as Annual Energy Yield, Mean Time Between Failures

and ability to survive expected operating conditions for the required lifetime.

The WES stage gate process uses consistent evaluation which both drives and mirrors the maturity of the candidate technologies, ensuring the best available information is used to make the optimal decisions at all stages. As the programme progresses, we're continually improving the way we apply metrics to the key evaluation areas.

OES: From your experience with performance metrics, what does an international agreement look like on this approach? What can be done to move towards consensus on ocean energy technology evaluation?

JH: Eventually, an agreement should provide a framework of required R&D activities and key metrics or evaluation criteria that the international community can use to guide and manage their funding schemes, technology development programmes and engineering projects.

A balance of consensus and flexibility is required here – wide agreement on the key metrics and evaluation methods, but with flexibility to allow governments, funders and investors to add additional metrics which may be specific to their chosen energy resource, market or objectives. The important thing is that this flexibility is additional to the core set of metrics that are applicable to all technologies, users, objectives and aspirations. Such an agreement will accelerate our progress towards cost effective energy generation from our oceans, enabling countries to benefit from each other's experience. This ensures the international community efficiently funds the best technologies and improves the global mobility of good technology solutions as developers search for investment, array deployments and industrialisation. This requires consistency – if a private investor or public funder looks at a technology developed in the Wave Energy Scotland programme, they will know exactly what engineering activities have been carried out, how the technology has been assessed and exactly what method was used to assess it – it breeds confidence that is in everyone's interest as we seek the massive rewards promised by the ocean energy sectors.

WES is working closely with the US Department of Energy, The European Commission and the IEA-OES members to achieve such an agreement. Between us we cover the full range of ocean energy technologies and have vast experience of supporting and guiding these sectors. We are sharing our experiences and working towards a common framework that supports all our needs, including that flexibility to allow the agreement to be useful in practice. The task will continue through 2019 and beyond as we work towards the common goal, with the IEA-OES being a trusted body that can engage interested stakeholders to facilitate international agreement and uptake of a common approach to stage gate metrics.

A common framework will guide technology developers to carry out the right research & development activities with the engineering rigour necessary to make the right decisions. This will result in reduced risk, increased confidence and accelerated success in the ocean energy sector.

05

INTERNATIONAL SITUATION ON OCEAN ENERGY

AUSTRALIA

OVERVIEW

A key highlight for Australia's ocean energy (OE) community was re-instatement of Australian membership in OES. Membership is currently supported by a grant from the Australian Renewable Energy Agency and their International Engagement Program. Improved communication and interaction nationally and with international community is already evident. Participation in the OES task groups is proving to strengthen domestic OE community connections and networks, which contributed to a highly successful second annual ocean energy conference in November 2018.

Notwithstanding the challenges, a number of Australian developers and researchers are engaged in a few well-advanced development and research projects, primarily tidal and/or wave energy. Four Australian companies are developing devices for local sites, and another 2 Australian company projects are planned for deployment outside Australia. One device, MAKO tidal, was deployed in an Australian port in 2018. A national wave energy resource assessment was completed in 2017 and is available via the Australian Wave Energy Atlas. A national tidal energy resource assessment is under way, and a new wave energy research centre has been established in Western Australia. A proposal to establish a centre for offshore wind and wave energy in South Australia has also been shortlisted as part of an Australia-China Science research-funding initiative. The industry continues to strengthen as a result of the formation of the Australian Ocean Energy Group (AOEG), a virtual ocean energy cluster, which evolved from the Australian Marine Energy Taskforce and seed funding provided by the National Energy Resources Australia (NERA). AOEG will be formally established in early 2019.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The lack of a national Ocean Energy Policy in Australia is a major challenge for the Australian OE sector. This is despite the fact that Australia has considerable wave and tidal ocean energy resources. The development of the emerging ocean renewable energy (ORE) industry could build Australia's

blue economy, while actively contributing to committed carbon mitigation measures (reference CSIRO report).

While there is no government-led policy, the sector has come together to produce a few key documents:

- a. A White Paper (Hemer et al) was also published in mid 2018 to document the recommendations arising from a stakeholders workshop held in late 2016. At the workshop, ocean energy technology and project developers, researchers, academics, policy makers and other stakeholders in Australia's emerging ocean energy sector came together to identify the challenges and develop possible pathways to grow ocean energy in Australia. The paper is titled: Perspectives on a wave forward for Ocean Renewable Energy in Australia, and is published in the journal, Renewable Energy (2018) 127:733-745. <https://doi.org/10.1016/j.renene.2018.05.036>.
- b. An 'economic survey' was commissioned by the former Australian Marine Energy Taskforce (AMET) and independently conducted by BDO Sydney. The report was completed in December 2018. The new AOEG is planning to complete a Commercialisation Support Plan in 2019, whose results are expected to contribute to future ocean energy policy development.
- c. The Commonwealth Australian Renewable Energy Agency (ARENA) commissioned an internal "ocean energy assessment" to review prospects for the medium- and long-term development of ocean energy in Australia. The report, completed and submitted to ARENA in November 2018, will influence future ocean renewable policy.

A number of actions were identified in the White Paper on Australian Ocean Energy (Hemer et al 2018), however these actions have not been prioritised. They include:

a. Technical/ Research actions

- **Engineering** - convergence of the device technologies to a reduced and optimal number of device types that best suited to Australian geographical or economic circumstances would be ideal. Also, some consideration of ORE best integrate with other low-emission energy technologies and storage solutions would help to focus Australian efforts in the OE sector.
- **A national test facility** - Establishment of a test facility is widely desired.
- **Data** - Establish multi-year datasets measuring performance and effects of deployment are needed. Also a regular review of the knowledge, and learnings from failures to identify knowledge gaps priorities for targeted research activities. A knowledge base on the potential environmental impacts of device deployment continue to be collected, preferably independent of the project proponent(s).

b. Policy and Regulation and environment actions

- Develop a **national policy framework** to continue

the growth of the renewable energy target beyond the current levels set for 2020-2030 in Australia.

- Clear **international guidelines for assessing technologies** would aid decision making processes. Developers will ideally follow **best practice pathways for technology readiness levels**.
- Australian **engagement in the international discussion for integrated ocean planning and management** with due consideration of ORE is required (Warner, 2012). A framework for **management of multiple sectors in the marine environment** is needed. Improving the consistency of marine policy between jurisdictions will support ORE project development. Appropriate planning frameworks would ultimately help the industry by smoothing the development process, giving greater certainty and timelines for approvals, providing social license to operate, and avoiding costs associated with potential approval-related project delays.
- **Strong engagement with indigenous Australia** should underpin ongoing development of ORE in Australian waters.

c. Communication actions

A sectoral voice to inform policy in Australia, via an Ocean Energy network is a strong need expressed by the sector. Great progress has been made in developing the Australian OE community network, with the reestablishment of OES membership, alongside the formation Australian Ocean Energy Group (AOEG).

The national Energy Policy governs ocean energy indirectly in Australia. The Australian government departments that deal with ocean energy include:

- Department of Environment and Energy
- The Australian Renewable Energy Agency (ARENA)
- Australian Energy Market Commission (AEMC)
- Clean Energy Regulator (CER)

In November 2018, an independent survey conducted by BDO Sydney assessed the economic significance of the ocean energy sector to Australia. For the year ending 30 June 2018 six ocean energy technology developers (wave and tidal) disclosed combined expenditures of approximately \$16.6m. Of this expenditure approximately 60% is paid to Australian residents, a strong economic investment in Australian expertise. Expenditure for next year (for the period from 1 July 2018 to 30 June 2019) is expected to substantially increase to \$29.5m – a 77% increase. This does not take into account the expanded economic value when all associated industry participants are included.

Investment in ocean energy research and development in Australia in 2018 included Commonwealth funding from the Australian Renewable Energy Agency and National Energy Resources Australia for ocean renewable energy

research projects totalled approximately \$AUD1.5m for 2018, with co-investment from project partners adding a further approximately \$AUD3m investment. The Western Australian State Government has been another major public investor, via the Albany Wave Energy Research Centre, with a further approximately \$AUD1m for research in 2018. Investment in research of a similar magnitude is expected for 2019.

MARKET INCENTIVES

There are currently no market incentives in Australia for ocean energy systems.

PUBLIC FUNDING PROGRAMMES

There are three national funding programmes that support ocean energy, including:

- Australian Renewable Energy Agency (ARENA)
- Clean Energy Finance Corporation (CEFC)
- National Energy Resources Australia (NERA)

Each of these agencies support a wide range of renewable and clean energy initiatives. This means that finding funding for ocean energy in Australia can be difficult, as any ocean energy initiatives and proposals must compete with more highly developed technologies for their funding.

RESEARCH & DEVELOPMENT

Overview of main research activities in 2018:

Following a successful project to map Australia's wave energy resource (<http://nationalmap.gov.au/renewables/#share=s-gGd5ztFcxe2ysy9f>), a project to map Australia's tidal energy resource (<http://austen.org.au/>) is in its second year – led by **University of Tasmania (AMC) and CSIRO**. The project will cover a number of fronts including:

- Implementation of **COMPAS (unstructured coordinate system)** on a national grid to assess national scale tidal resource. The unstructured mesh (COMPAS <https://research.csiro.au/cem/software/ems/hydro/unstructured-compas/>) is constructed using a dual weighting function, being a function of both bathymetry and tidal amplitude, to achieve highest resolution in regions of higher interest. A neap-spring simulation has been completed, with ongoing development of COMPAS code (parallelisation), refinement of the model mesh, calibration and validation activities ongoing.
- Developing **Multi Criteria Evaluation** of prospective tidal energy sites in Australia. This process will use weighted selection methodology to identify regions with both large tidal resources, demand for power and capacity to grid and off-grid connections.

- **A field campaign.** The team is processing the data from a field campaign site in the Banks Strait, Tasmania, and selection of second site is under consideration. Further development, calibration and validation of fine scale numerical model at the first site and integration of tidal turbine arrays is under way.
- Plans to develop **technical and economic modelling** of integrating tidal turbine arrays at the suitable tidal locations.

A new hub for marine energy research and innovation, the **Wave Energy Research Centre (WERC)**, is led by the **University of WA** and is collocated in Perth and Albany was established in 2018. Over 30 research staff are working at the centre in marine renewable energy (including approximately 10 PhD students), working across, metocean analysis, physical oceanography, hydrodynamics and offshore geotechnical engineering.

WERC was established with funding from the Australian Research Council and ARENA, totalling about \$2.2M. \$3.75m of "Royalties for Regions" funding from the WA Government over a 4-year period and \$1M matching contribution from UWA (+\$6m in-kind). A specific aim of the WERC is Assist with the development of the Albany Wave Energy project by Carnegie Clean Energy (CCE), with contributions including:

- analysis of operational performance of CCE CETO6M wave energy converter, with outcomes to be used to design the device against extreme conditions and yaw instability;
- wave-by-wave prediction models are also being developed to optimise CETO6M energy generation performance;
- Torbay resource assessment and development of a locally adapted numerical model (with 35-year hindcast and real-time capability) and a coupled wave-circulation model.

University of Adelaide is working with Carnegie on multimodal point absorbers control systems using local HPC 400Megaflops and 5634 cores for numerical experiments, validated with local flume experiments. Two devices of interest, multi-moored device similar to CETO6, and a single point mooring asymmetric point absorber, are both demonstrating greater power returns than traditional devices. The university proposal to establish **new Joint Australia-China Research Centre for offshore wind and wave energy** has been shortlisted to the final 16, where 6-7 will be funded. A final decision expected in December 2018 for a start in early 2019.

Swinburne University of Technology - Ongoing activities include a PhD project on nonlinear WEC behaviour with an emphasis on coastal protection, and projects on laboratory and numerical modelling of environmental impacts of WECs.

University of NSW Water Research Lab is undertaking a study of tidal energy in the Cook Islands. They have

completed a 6-month field investigation on the potential of tidal energy in the Cooks Islands with deployment of multiple instruments in Muri Lagoon. This new field data will be used to perform a more detailed resource assessment along Rarotonga shoreline. The potential for coastal protection benefits of ORE and the impact on beach recovery post-storm will also be considered.

Griffith University Centre for Coastal Management is focused on wave climate studies at both the global and very nearshore local scales, and is also active in coastal processes research which may be useful, for example, for studies into the interaction of OE technology with the coastal ocean/morphology. A Coastal Engineering Research Field Station on the Gold Coast funded by an ARC LIEF grant in collaboration with the Gold Coast Waterways Authority, University of Queensland and University of Newcastle, has a range of monitoring equipment including a wave radar, manometry, lidar and cameras. Monitoring data collected will assist with wave climate model development and performance evaluation in the very nearshore. A 1979 to present wave hindcast dataset for the nearshore coastal waters of the Gold Coast region extending down to Ballina in the south and the Sunshine coast in the north is under development. This model is a downscaling of CAWCRs CFSR driven hindcast. Evaluation of 2D wave spectra model output is planned against wave buoy derived spectra including global scale hindcast datasets and locally downscaled model output. This will contribute to the analysis of the latest COWCLIP global wave climate ensemble to quantify the sources of uncertainty and variance amongst the ensemble members.

TECHNOLOGY DEMONSTRATION

PROJECTS IN THE WATER

There are aspirations to establish test sites in Australia, but there are none yet.

MAKO Tidal Turbines has installed a MAKO turbine system at Gladstone Port, a large port in eastern Australia.

PLANNED DEPLOYMENTS

Projects under development planned to be soon deployed in the sea include:

- **BOMBORA** is currently working on the financial arrangements for their first commercial array project in Europe after the completion and validation of their mWaveTM prototype of 1.5 MW in Wales;
- **MAKO Tidal Turbines** installed a MAKO turbine system at a large port in Australia while simultaneously progressing to a demonstration site in South East Asia;
- **Nandy's R&D Pty Ltd** has moved through the proof of concept stage with plans to develop a full-sized pilot project;

- **Wave Swell Energy** is working on funding its 200 kW wave energy project to be located on King Island;
- **Carnegie** is moving now with the design of CETO 6 wave energy device of 1.5 MW.

RELEVANT NATIONAL EVENTS

Australian ocean energy events in 2018 included:

- Australia recently held its **2nd Australian Ocean Renewable Energy Symposium** (AORES; Perth, Nov 21-23, 2018) following on from the very successful inaugural symposium held in Melbourne in 2016. AORES fosters collaboration and future growth of the Australian ocean renewable energy sector (wave, tide and offshore wind) by bringing together industry, academics, policy makers and other stakeholders to share information on the latest domestic developments and scientific advancements. At both AORES events a number of international and industry leaders delivered keynote presentations providing valuable a global context.
- As part of AORES 2018, an **ocean energy Industry Roundtable** was held including: a Developers Showcase with presentations from Australian OE companies, on their respective technologies and their emerging markets; plus two separate panel discussions on market opportunities for ocean energy technologies, one focused on domestic opportunities and the second one on export opportunities.
- **Tidal Energy Workshop (Nov 2018 Perth)** – a full day workshop was held to share the results to date of the AUSTEn project, a three-year project to map Australia's tidal energy resources in unprecedented detail, as well as assess Australia's tidal energy's economic feasibility and ability to contribute to Australia's energy needs.
- **All Energy symposium held October 2018** – a well-attended and engaging marine energy panel discussion was held.

Two international events will be held in Australia in 2020:

- Asian Wave and Tidal Energy Conference (AWTEC) 2020, will be hosted by University of Tasmania (AMC) and CSIRO.
- 31st International Conference on Coastal Engineering (ICCE) 2020 – will be co-hosted by UNSW, Water Research Laboratory (WRL) in September with a marine renewable session likely.

Other relevant activities

Members of the Australian ocean energy community expressed strong interest in joining the International Electrotechnical Commission Technical Committee 114 (IEC TC114). In 2018, national coordination was initiated by AMET and discussions are under way with Standards Australia to establish Australia's membership in the international committee.

BELGIUM

In the coastal province of West Flanders, Western part of Belgium, marine renewable energy is seen as a new emerging market, highly relevant for Flanders and Belgium. There are several initiatives promoting the development of the blue economy, including marine energies.

OVERVIEW

In the coastal province of West Flanders, Western part of Belgium, marine renewable energy is seen as a new emerging market, highly relevant for Flanders and Belgium. There are several initiatives promoting the development of the blue economy, including marine energies.

The 'Strategic Framework for Smart Specialisation in Flanders', describing the on-going policy process for proprietary areas in the innovation and strategy of Flanders, points out the sectors of Blue Economy, Blue Growth and Blue Energy in Flanders as prioritised areas. WESTDEAL is then focussing on West Flanders.

The West Flanders Development Agency (POM West Flanders), responsible for the implementation of the social economic policy of the Province of West Flanders, is supporting developments in the blue energy field, promoting the development of ocean energy technology by the academic sector and private companies. Factory of the Future "Blue Energy" is the action plan of the province of West-Flanders (POM). Moreover, POM has introduced TUA West, an agency that acts as a liaison between partners from various industries and civil society, supporting the triple helix model of establishing links between companies, knowledge institutions and governments.

The Flemish Agency for Innovation and Entrepreneurship (VLAIO) has been supporting a new 'Innovative Business Network Offshore Energy' since 2017 and in 2018 set up and a 'Blue Cluster' aimed at large companies & SMEs active in the blue economy sector, including marine energies.

Belgium has become member of the Europe Leading Blue Energy (ELBE) project aiming to position Europe as the world technological and industrial leader in "blue" energy.

A relevant European funded project - MET-CERTIFIED - coordinated by the Dutch Marine Energy Centre is developing recognised standards and certification schemes in the sector. Ghent University and POM are the Belgian partners in MET-CERTIFIED.

Ghent University is coordinating the recently approved COST Action CA17105 "WECANET: an open pan-European Network for Marine Renewable Energy with a focus on wave energy", which supports training, networking and collaboration in Europe. This project is funded by the European COST Association and involves 30 countries.

The Flemish wave energy developer Laminaria is developing a 200 kW prototype to be tested at EMEC's grid-connected wave test site in 2019, through the European funded project LAMWEC.

Ghent University is strategic partner in the H2020 MARINERG-i project coordinated by the MaREI Centre at University College of Cork Ireland, which brings together all the European countries with significant testing capabilities in offshore renewable energy. MARINERG-i is developing a plan for an integrated European Research Infrastructure, an independent legal entity, designed to facilitate the future growth and development of the Offshore Renewable Energy sector. Ghent University is participating in MARINERG-i with marine energy technologies testing infrastructure which includes wave flumes and the new Coastal and Ocean Basin.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

Belgium has to increase its share of renewable energy production to 13% of the total consumption by 2020, following the general European Union objective. This share has been growing steadily in the last year. Currently, Belgium's renewable energy share is at around 9%, with a 2020 target of 13%.

Main incentives aim at wind energy (onshore and offshore), biomass, biogas and solar energy. The offshore wind energy concessions in the Belgian North Sea will have the biggest impact on renewables, leading up to a total of ± 2200 MW of offshore wind power installed by 2020.

A green energy certificate market is implemented to support onshore renewable energy production with Tradable Green Certificates (TGC). For each renewable technology, a stakeholder analysis is put forward to determine the level of support. A generic business case is constructed with input of the developer, the technology supplier, investors, banks, etc. This exercise will determine the cost of the renewable electricity and the matching value of the TGC in €/MWh. The business case is frequently updated in order to align the new TGC support with the technology evolution.

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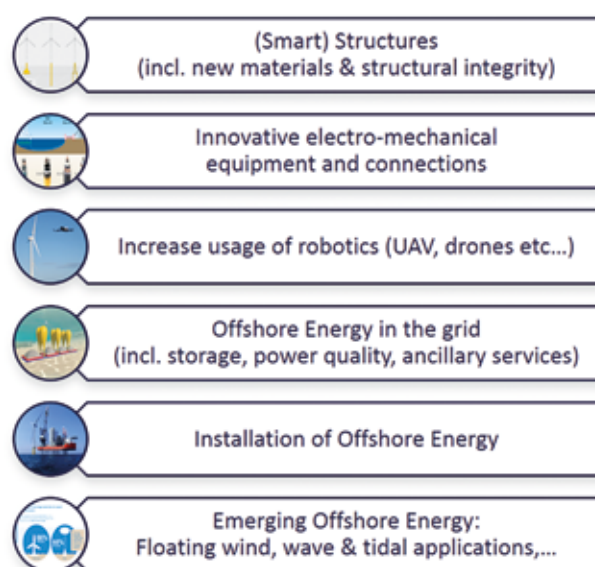
MARKET INCENTIVES

The Belgian maritime spatial plan foresees an area for the exploitation for offshore wind, wave and tidal energy. This area has been divided into 9 zones for which the Government has given concessions for alternative energy project development. The last concession (± 55 km from the coast) was granted in July 2012 to the temporary trading company Mermaid. This Mermaid concession zone aims at the installation of 232 to 266 MW wind and 5 to 61 MW wave energy (rated power). This hybrid park has a water depth of 35-40 m and an average wave climate of 6.5 kW/m. The project is planned to be finished by 2020 for wind part of it.

The Flemish Agency for Innovation and Entrepreneurship (VLAIO) has been supporting a new '**Innovative Business Network Offshore Energy**' (**IBN-Offshore Energy**) since 2017 and in 2018 set up and a '**Blue Cluster**' aimed at large companies & SMEs active in the blue economy sector, including marine energies. Further activities within the '**Blue Energy Cluster**' aim at supporting Belgian companies from the ocean energy sector.

IBN-OFFSHORE ENERGY

The **IBN-Offshore Energy** (<http://www.offshoreenergycluster.be/>) is a network of Flemish companies innovating in the field of offshore energy (offshore wind, floating wind, wave & tidal). The activities of the IBN Offshore Energy are oriented towards facilitating innovation in this area.



IBM-Offshore energy

The cluster's mission consists of facilitating the process for its clients by which a concrete idea becomes a fully-realized project plan for a new product or service within the offshore energy sector (focus = offshore wind, wave & tidal energy). Within this innovative business network (IBN) the focus is laid upon RD&I support, knowledge sharing and networking between the members and external.

The IBN-Offshore Energy focusses on a number of themes that are relevant to companies operating in the cluster activity. The cluster keeps track of the market and technology developments within these themes and inform its members about the current RD&I calls. In addition, the IBN-Offshore Energy facilitates matchmaking between members regarding these themes and look for opportunities for tackling mutual challenges and opportunities (cluster actions). The IBN-Offshore Energy also looks for international collaborations that would be useful to the cluster.

THE BLUE CLUSTER

The Blue Cluster (<https://www.blauwecluster.be>) has been established in the beginning of 2018 and was recognized by the Flemish government as a spearhead cluster in March 2018.

Highlights about members of the Blue Cluster:

- DEME Blue Energy is a specialized company that focuses on the development of energy generated from waves, tidal movements and tidal currents. DEME Blue Energy installed the four turbines of MeyGen's Phase 1A and is involved in the development of two additional tidal energy parks in Scotland and Northern Ireland.
- IMDC is partner in the SE@PORTS project. Funded by OCEANERA-NET, the main goal of the SE@PORTS project is to assess existing WEC's (proven concept TRL 3) on their suitability to be integrated in seaport infrastructures and bring the selected concepts of WEC's to the next TRL.
- The Laminaria wave energy buoy has an innovative load management mechanism and storm protection system. Development has been supported by the Flemish agency for innovation as well as through several European projects. After successful tests at Plymouth and Ostend, next phase is at EMEC in Scotland.
- Belgian ENGIE affiliate Tractebel was involved in the pre-feasibility study, technical audit and foundation design of the Raz Blanchart tidal energy pilot project in France.
- In October 2018, a first "Task force meeting" was held in Ghent (Belgium), to discuss priorities and roadmaps for all 6 domains of activity of the Blue Cluster.

THE BLUE ENERGY CLUSTER

In order to help businesses in West Flanders to grow regionally and internationally via innovation, the Province



Task force meeting held in October 2018, to discuss priorities and roadmaps for all 6 domains of activity of the Blue Cluster, which includes Marine Renewable Energy

of West Flanders established cluster platforms in the framework of the Provincial Development Agency West-Flanders (hereafter referred to as POM) to proactively prepare its industries for the future.

The Blue Energy cluster, focusing on wind, wave and tidal energy, is situated at the Belgian coast and in the Ostend area in particular. Through a partnership between all relevant actors at the local, provincial and Flemish level SMEs are supported in their future-oriented and sustainable development: from practical services to promotion, research, training and infrastructure: the cluster platforms aim to create an optimal breeding ground for a future-oriented economy.

Brochure: http://www.investinwestflanders.org/sites/default/files/Blue_Energy.pdf

Website: <http://www.fabriekenvoordetoeekomst.be/fabrieek-voor-de-toekomst-blue-energy>

PUBLIC FUNDING PROGRAMMES

The federal Energy Transition Fund aims to encourage and support research and development in the field of energy. As part of the Energy Transition Fund, the Directorate-General Energy organizes each year a call for proposals. The current call aims to support innovative and research projects within five energy sectors of federal scope with that of renewable energy in the Belgian exclusive economic zone of the North Sea being one of them.

The Energy Transition Fund aims at research and development in the field of energy. The budget of the Energy Transition Fund for the year 2019 amounts to 30 million euros, which can be awarded as a subsidy to projects that meet all relevant conditions and relate to research and development, investment in research infrastructure, innovation clusters or on innovation by SMEs.

RESEARCH & DEVELOPMENT

MARINERG-i

Ghent University (<http://awww.ugent.be>) is strategic partner in the H2020 MARINERG-i project (www.marinerg-i.eu) coordinated by the MaREI Centre at University College of Cork Ireland, which brings together all the European countries with significant testing capabilities in offshore renewable energy. MARINERG-i is developing a plan for an integrated European Research Infrastructure, an independent legal entity, designed to facilitate the future growth and development of the Offshore Renewable Energy sector. Ghent University is participating in MARINERG-i with marine energy technologies testing infrastructure which includes wave flumes and the new Coastal and Ocean Basin (www.cob.ugent.be).

Gen4Wave project – Coastal & Ocean Basin

The Flemish government decided to invest 5M euros in the Gen4Wave project. The Board of Directors of the Hercules Foundation approved the proposal by Ghent University and KU Leuven for research infrastructure coupled to Gen4Wave for an amount of 2.3M euros. Gen4Wave is the start of an investment project, including the construction and start-up of a wave tank, featuring waves, currents and wind loads, as test infrastructure for coastal engineering and offshore renewable energy in Flanders.

The new Coastal and Ocean Basin (COB) at the GreenBridge campus in Ostend is planned to be operational in 2019. The facility is part of the Gen4Wave project on renewable energy and coastal engineering in Flanders, Belgium, and is co-funded by the Hercules foundation and the Ministry of Mobility and Public Works.

WECANet

WECANet (www.wecanet.eu) is the new European COST Action network of 30 countries dedicated to Marine Renewable Energy, with a focus on Wave Energy. WECANet is funded through the HORIZON2020 Framework Programme by COST (European Cooperation

in Science and Technology, www.cost.eu), a funding agency for research and innovation networks. WECANet fosters transnational collaboration, the organisation of training on Marine Renewable Energy topics (international Training Courses), the realisation of the so-called “Short Term Scientific Missions” between researchers of different countries, networking events and dissemination activities. In Belgium, WECANet is coordinated by the

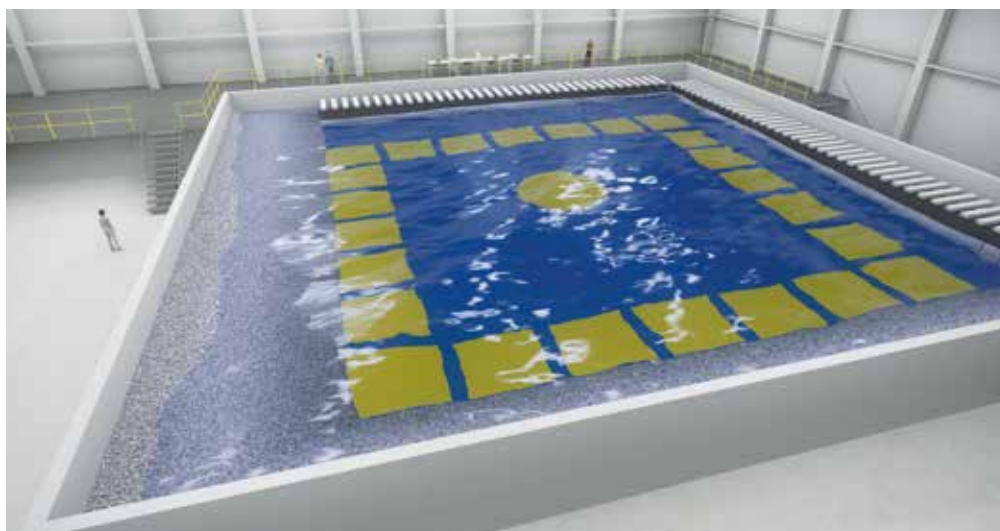


The 30 WECANet COST Action partners (in colour)

Coastal Engineering Research Group of Ghent University (UGent-CERG) and is actively supported by activities of the Flanders Marine Institute (VLIZ, <http://www.vliz.be>), the Marine@UGent cluster and the Provincial Development Agency West-Flanders (POM).

PhD research projects at Ghent University dedicated to wave energy research

The Research Foundation Flanders (FWO, <https://www.fwo.be/>) funded in 2018 six PhD research projects (two of them by the previous “IWT”), on wave energy topics, all of them carried out at the Coastal Engineering Research Group of Ghent University.



Visualisation of the new Coastal and Ocean Basin (COB) in Belgium, a testing infrastructure for Marine Renewable Energy.

The European 'EsflowC' MaRINET2 project

In 2018 the European 'EsflowC' MaRINET2 project has been completed. EsflowC (Efficiency & survivability of floating OWC) is a research project of 7 partners coordinated by the Coastal Engineering Research Group of Ghent University. The main purpose of this research project is to test the OWC WEC response and mooring line tensions using different types of mooring materials and different wave conditions.

MET-CERTIFIED

This project (www.met-certified.eu) aims to increase the adoption of insurable and therefore bankable marine energy projects in the 2 SEAS region through the development of internationally recognised standards and certification schemes in the sector. At present no certification scheme for marine energy have been developed and implemented by all main stakeholders in a consistent way. The expectation is that it will come into existence over the next years under the umbrella of the International Electrotechnical Commission (IEC). Therefore, the timing of MET-CERTIFIED is very favorable. MET-CERTIFIED brings together partners from 4 European countries to advance the marine energy sector in the 2SEAS region. MET-CERTIFIED is funded by the European Interreg 2 Seas programme and co-financed by the European Fund for Regional Development (ERFD). Further, the Ministry of Economic Affairs in the Netherlands, Province of South-Holland and North-Holland and the Belgian Province of West Flanders are offering financial support.

DUAL ports

This project (www.dualports.eu) is coordinated by the harbour of Ostend, Belgium, with funding from Interreg North Sea. DUAL Ports aims to decarbonise Regional Entrepreneurial Ports (REPs) resources through a shared eco-innovation port program that minimises their environmental footprint. The objective is to specifically develop sustainable utilities and abilities of REPs. This will be achieved by collaboratively piloting and managing technologies and processes that tackle targeted measurable direct/indirect emission/pollution sources. The project will ultimately enhance ports organizational/operational (energy) efficiency and performance, facilitating port low carbonization at reduced cost and with knowledge/investment added value.

Ports Energy and Carbon Savings (PECS)

This project (<http://www.pecs2seas.eu/>) aims to develop, test and implement different tools and technologies in order to reduce the carbon footprint of the Small and Medium sized Entrepreneurial (SME) ports and marinas, and to make their functioning more energy-efficient in a cost-effective way. Next to their own contribution, the PECS partners receive funding from Interreg 2 Seas programme 2014-2020, the European Regional Development Fund, the Provinces North and South Holland.

Integrating Tidal Energy into the European Grid

An €11 million Interreg North-West Europe (NWE) project has been launched in Orkney to develop an all-in-one

solution for the generation of clean predictable energy, grid management, and the production of hydrogen from excess capacity. Led by the European Marine Energy Centre (EMEC) in Orkney, the €11m Integrating Tidal Energy into the European Grid (ITEG) project brings together partners from across the UK, France, Belgium and the Netherlands to address energy-related carbon emissions in North-West Europe and tackle grid export limitations faced in remote areas such as Orkney.

More information: <http://www.nweurope.eu/projects/project-search/iteg-integrating-tidal-energy-into-the-european-grid/>

Link2Innovate

This project (<http://www.link2innovate.eu>) is an Interreg project run by Greenbridge, an incubator focused on blue growth located in West Flanders. Flemish and Dutch incubators match techno starters with larger companies for a joint innovation project of 1 year. GreenBridge facilitated 4 matches in the area of blue energy: operation and maintenance of blades, structural health monitoring in blue piling technique, wave prediction software development and inspection of port infrastructures by aquadrone.

COASTAL

This project (<https://h2020-coastal.eu>) is coordinated by Greenbridge and has the ambition to connect and reinforce the different policies for a sustainable use of marine space, exploiting new development opportunities related to blue growth.

GreenBridge

GreenBridge is an incubator focused on blue growth located in West Flanders. It hosts triple helix representatives that play a key role in unlocking blue growth in the region. Science is represented through the expertise of Ghent University.

Blue Growth Summer School

The Blue Growth Summer School (BGSS) is organised by Greenbridge and is recognized by the European Commission as best practice example of innovative training on Blue Growth, including Ocean Energy. Three years on row the BGSS has gained momentum increasing the participants and their diversity. More information: <http://www.bluegrowth.ugent.be/summerschool/>

Europe Leading Blue Energy (ELBE)

The ELBE project is supported by the EU COSME-programme. ELBE partners want to position Europe as the technological and industrial world leader in blue energy. Five European clusters, including Flanders' Maritime Cluster (soon De Blauwe Cluster), join forces to shape a pan-European blue energy cluster with global ambitions. The focus is on wave energy, tidal energy and floating offshore wind energy. For each of these domains, the ELBE partners select the most important growth markets worldwide through a market analysis.

More information: website: <https://www.blauwecluster.be/project/elbe-europe-leading-blue-energy>

Blue Accelerator

This project aims to create a living lab of near and offshore test facilities with the possibility for knowledge institutions and companies to test blue energy and blue growth innovations in real life sea conditions. Main element of this project is the realisation of an offshore test platform, which will be operational mid-2019 and be open to both companies and knowledge institutions for testing.

TECHNOLOGY DEMONSTRATION

PLANNED DEPLOYMENTS

LAMWEC

The Flemish wave energy developer **Laminaria** is developing a 200 kW prototype to be tested at EMEC's grid-connected wave test site (the European Marine Energy Centre in Orkney, Scotland) in 2019, through the European funded project LAMWEC.



LAMWEC

NEMOS

A German wave energy developer, **NEMOS**, is focussing on the installation of a large-scale prototype in the Belgian North Sea. With a floater displacing more than 10 m³ water and a fully equipped powerhouse on an independent structure, the system will generate enough energy to supply several households with electricity.

RELEVANT NATIONAL EVENTS

Key relevant events in 2018:

- 5 December 2018: IBN Offshore Energy - General Assembly
- 8 November 2018: Seminar Offshore cables organised by IBN Offshore Energy.
- 5 October 2018: Seminar Emerging Offshore Technologies - Wave-Tidal and Floating wind power organised by IBN Offshore Energy.
- 10 - 21 September 2018: Blue Growth Summer School organised by Greenbridge
- 12 September 2018: European COST Action 'WECANet' launch meeting in Brussels, organised by the Coastal Engineering Research Group of Ghent University.
- 23 March 2018: Meeting of Belgian Stakeholders for Marine Renewable Energy within the activities of the HORIZON2020 project MARINERG-i, organised by the Coastal Engineering Research Group of Ghent University.

CANADA

2018 was an exciting year for Ocean Energy development in Canada and a highlight was the hosting of the G7 Environment and Energy Ministers meeting in Nova Scotia to discuss the Blue Economy. This meeting gave Canada a chance to feature the efforts being made across Canada in Ocean Renewable Energy.

OVERVIEW

2018 was an exciting year for Ocean Energy development in Canada and a highlight was the hosting of the G7 Environment and Energy Ministers meeting in Nova Scotia to discuss the Blue Economy. This meeting gave Canada a chance to feature the efforts being made across Canada in Ocean Renewable Energy. Marine Renewables Canada (MRC), the Fundy Research Centre for Energy (FORCE) and most of the tidal power developers building projects in Canada had the opportunity to address the ministers and participate in discussions.

In Canada, provincial governments have exclusive jurisdiction over the development and management of sites and facilities for the generation of electrical power within the territory of their respective provinces. Nationally, through the departments of Natural Resources (NRCan), Fisheries and Oceans (DFO) and Environment (EC), Canada supports and provides funding for projects as well as regulates the environmental impact. In 2018 the federal government proposed Bill C-69, which will expand federal authority in offshore projects, this is currently in review. The provinces build legislation, assess resources, collect royalties and assign incentives.

In the ocean energy sector in Canada regional interest is focused on:

- British Columbia (BC) – Wave, tidal, river hydrokinetic and offshore wind;
- Manitoba (MB) – River hydrokinetic;
- Ontario (ON) – River hydrokinetic;
- Quebec (QC) – River hydrokinetic;
- Nova Scotia (NS) – Tidal and offshore wind and;
- Newfoundland (NL)– Wave, offshore wind;

In 2018 there were significant milestones achieved and also some changes to the way Ocean Energy will be pursued in Canada. In tidal power, Cape Sharp Tidal successfully deployed in the Minas Passage Nova Scotia FORCE site for the third time and although the company was dissolved very soon after, the turbine was successfully connected and produced tidal power for the second time on the Nova Scotia grid. Following this, indications are that in the Bay of Fundy, floating systems could be the tidal power platforms of choice for the foreseeable future.

Black Rock Tidal Power, renamed as Sustainable Marine Energy Canada (SMEC) as of January 2019, successfully deployed the floating PLAT-I system from Sustainable Marine Energy (UK) in Grand Passage, Bay of Fundy, NS. This is a lower energy site than Minas Passage in the Bay of Fundy and the platform was deployed without turbines so that SMEC can complete a series of environmental monitoring and research baseline tasks before generating power. Halagonia Tidal Energy Ltd. (HTEL), a Canadian subsidiary of DP Energy is also developing a floating system and Big Moon Power has a floating system. The Cape Sharp Tidal berth at FORCE was sold at the end of 2018 and the new technology developer and project developer will be announced in early 2019.



SMEC Plat-I Installation, Grand Passage, NS, photo credit: SMEC



Installation of FAST platform, photo credit: FORCE

In 2018 the Canadian and provincial governments have invested in excess of \$34M directly in ocean energy projects and in excess of \$700M in external programs for which ocean energy projects are eligible. It is anticipated that there will be investments of \$20M plus directly in ocean energy projects in 2019.

Canada saw extensive work completed in environmental monitoring and resource assessment in 2018. This work was performed primarily in NS and BC. In NS, FORCE and some of the developers completed a large number of projects. In BC, the West Coast Wave Initiative (WCWI) of the University of Victoria (UVic) deployed 5 wave monitoring buoys and one Ocean Sentinel (in collaboration with Danish company Orsted).

Marine Renewables Canada, with partners at the Government of Canada have published a 'State of the Sector Report' highlighting the opportunities, challenges and path forward to capturing opportunities in the ocean energy in Canada and globally.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The national strategy for ocean energy has built upon the Canadian Marine Renewable Energy Technology Roadmap which was launched in 2011. Provincially, the NS government developed the Marine Renewable Energy Strategy in 2012 and the BC government has an ocean energy land use policy, a marine energy atlas and is supporting the development of case studies for wave energy in BC communities.

In February 2018, under Bill C-69, the federal government proposed the Canadian Energy Regulator

Act, which will provide the new Canadian Energy Regulator (currently the National Energy Board) with the authority to regulate the construction, operation and decommissioning of offshore renewable projects (tidal, wave and offshore wind) and their associated power lines in federal offshore areas. The federal government is now working towards the development of offshore renewable energy safety regulations under the proposed Canadian Energy Regulator Act. Under Bill C-69, the federal government also proposed the Impact Assessment Act (replacing the current Canadian Environmental Assessment Act 2012), which will establish the Impact Assessment Agency of Canada (currently the Canadian Environmental Assessment Agency) to lead all federal impact assessment reviews of major projects, working with other regulatory authorities, such as the new Canadian Energy Regulator, and in cooperation with provinces and territories and Indigenous jurisdictions. Bill C-69 is undergoing Parliamentary review and is expected to become law in spring 2019.

In NS, the Marine Renewable Energy Act was acclaimed into legislation in 2018. This means that identified Marine Renewable Energy Areas (MREAs) are designated in the legislation and can be assessed and added to the legislation in the future. Going forward, there will be competitive bids for licenses to produce power in an MREA that will come with a power purchase agreement (PPA) and outside of the competitive process, power production permits can be allocated by the NS Department of Energy and Mines (NS-DOEM). Currently there are 10MW allocated to the permit program and 5MW was awarded to Big Moon Power in 2018. In the permit system the project proponent must propose a project and a PPA that can then be approved by the Minister of Energy and Mines. The remaining 5MW of power production are currently open for application.

MARKET INCENTIVES

Under the changes to Nova Scotia's Marine Renewable Energy Act, projects that receive a permit can also receive a PPA of up to 15 years at a price set by the Minister of Energy. Any utility in Nova Scotia will be required to procure all electricity under the PPA.

Developers with projects at the Fundy Ocean Research Centre for Energy (FORCE) – Minas Tidal Limited Partnership, Black Rock Tidal Power, Atlantis Operations Canada, Halagonia Tidal Energy Limited, and Cape Sharp Tidal Venture – have approvals for Nova Scotia's Development feed-in tariff (FIT) for 53 cents/kWh and allows them to enter into a 15-year power purchase agreement with Nova Scotia Power, the provincial electric utility.

• Province of BC

- The clean energy act has a feed in tariff that exists in legislation but has yet to be implemented;
- First Nations in BC have the right to negotiate PPAs for renewable energy projects, including ocean energy, with BC Hydro under the micro standing offer program;
- BC Hydro will prepare a new Integrated Resource Plan in 2019 to incorporate new objectives for clean energy set forth by the BC government. It is anticipated that there will be opportunities for ocean energy projects in this new plan.

• Province of NS

- Feed in tariff program for projects at the FORCE site;
- Permit and licensing program with negotiated PPA.

PUBLIC FUNDING PROGRAMMES

A number of departments both federally and provincially contribute to the development of ocean energy in Canada. Energy ministries provide funding for projects and regulatory oversight, research fisheries, ocean and environment provide environmental and resource oversight and economic and knowledge development ministries provide incentives for hiring and training.

Because provincial governments have exclusive jurisdiction respective provinces, decisions regarding the development of ocean renewable energy resources (e.g. tidal, and wave) within provincial territory are made by each province. In some cases, determining the boundaries of a province in the offshore can be complicated. If the definition of a province's boundaries explicitly includes an area of the offshore, then that offshore is within the boundary of the province. Absent this explicit definition of a province's boundary, the general rule is that the low-water mark along the coast marks the provincial boundary. This general rule is further modified by the principle that inland waters are also within a province. Inland waters typically include harbours, bays, estuaries and other waters that lie "between the jaws of the land." Seaward of

these boundaries, provinces do not have property rights in the territorial sea. The federal government has the property rights seaward of these boundaries.

Ocean renewable energy represents a unique circumstance in Canada in that there is the potential for electricity projects to be situated in areas outside of the territory of a province, in marine areas under federal jurisdiction. In these circumstances, it is the federal government that is responsible for making decisions regarding the administration and regulation of ocean renewable energy activities.

Regardless of where an ocean renewable energy project is situated, and consequently which level of government is responsible for the allocation of rights and permits, a number of federal regulatory approvals are likely required. This stems from the federal government's responsibility over a number of issues in all areas of Canada's offshore, including fisheries, navigation, and certain environmental issues.

With a view to support the Pan-Canadian Framework on Climate Change and Clean Growth as well as the Federal Government's Innovation and Skills Plan, the Federal Government outlined \$2.3 Billion of investments in 2017 to support clean technology innovation and adoption. 2018 focused on implementing these funding investments.

Included in these investments was funding to create a Clean Growth Hub that would serve as a whole-of-government focal point for clean technology. The core function of the Hub, established in early 2018, is to help clean technology innovators and adopters identify federal funding and services for which they may be eligible. The Hub is co-chaired by Natural Resources Canada (NRCan) and Innovation, Science and Economic Development (ISED) and currently includes fourteen other federal departments and agencies whose mandates are supported by Canadian success in clean technologies. The Hub is well positioned to assist entrepreneurs and adopters of ocean energy systems identify potential funding to the specific needs of the project.



Deploying instrumentation at FORCE, photo credit: FORCE

In 2018, several funding programs were open to (but not exclusively dedicated to) support ocean energy such as Natural Resource Canada's Clean Growth in Natural Resources Program (\$155M/4 years to support RD&D), Emerging Renewable Power Program (\$200M/5 years) and the Clean Energy for Rural and Remote Communities Program (\$220M/6 years). These programs were aimed to help develop and support innovation for clean energy technologies across Canada.

Ocean energy technologies that were closer to commercialization, have been eligible for funding from Sustainable Development Technology Canada (SDTC), and Global Affairs Canada (GAC), and increased financing support through the Business Development Bank of Canada (BDC) and Export Development Canada. These government corporations offer programs to help de-risk projects for Canadian companies and projects. SDTC offers funding for 1/3 the cost a project usually in the range of \$3M. Global affairs offer a number of programs including assistance with attracting investors. BDC and EDC offer ways to reduce risk on companies in financing and exporting through a number of programs

including direct financing and insuring international purchase orders.

In November of 2018, the federal government unveiled the winners of the Innovation Superclusters Program which included committing \$950M to five industry consortiums, including Canada's Ocean Supercluster (OSC). This industry-led collaboration seeks to build Canada's ocean economy into a significant and sustainable value-creating economic segment and \$153m federal funding was announced for the OSC. It is built around a critical mass of ocean-based companies in Atlantic Canada and includes partners that span the ocean economy including marine renewables. Emera Inc., a long-time supporter of tidal power is an industry leader in the OSC.

\$29.8Million in the HTEL project through the Emerging Renewable Power Program in support of its \$117-million 9 MW instream tidal project in FORCE site, Nova Scotia. The Canadian government also invested \$1.5M for ocean technology and tidal research projects funded through the Offshore Energy Research Association (OERA) of Nova Scotia and \$725k in wave energy projects in BC.

RESEARCH & DEVELOPMENT

Research activities across Canada have encompassed environmental monitoring and technology development, resource assessment, power extraction technology demonstration and optimisation, numerical modelling and small-scale testing.

Regional research organisations support research in ocean energy and partner with industry and academia to move the state of the art forward.

OERA

OERA secured federal funding from Atlantic Canada Opportunities Agency (ACOA) and NRCan that was allocated to ocean technology and tidal energy. This enabled OERA to support 34 projects that were completed over a range of subject areas.

Active projects supported by OERA also under the themes of environmental monitoring, marine operations or cost reduction technologies include:

- a turbulence study and a fish tagging study at Acadia University;
- a marine operations study at Nova Scotia Community College (NSCC);
- lobster study with Big Moon Power;
- ROV use in tidal environments, NSCC;
- a fish and turbulence study led by FORCE.

Projects had in total 66 students working on tidal power research in 2018 and the cumulative total of \$2.6M in funds offered by OERA for all the active projects was leveraged to reach an overall total of \$6.5M in funding for tidal power related projects in NS. OERA will continue to offer its open call program in 2019 and expects additional funding programs to be announced throughout the year.



Fish and Shoreline Surveying, FORCE, photo credit: FORCE



Sensor deployment, FORCE, photo credit: FORCE

FORCE

Since the commencement of FORCE's latest monitoring efforts in May 2016 to the end of 2018, FORCE has completed:

- approximately 2,600 'C-POD days' (marine mammal monitoring days);
- 408 hours of hydro-acoustic fish surveys;
- 11 days of lobster surveys using 32 traps;
- four drifting marine sound surveys and additional sound monitoring;
- 42 observational seabird surveys; bi-weekly shoreline observations;
- commenced a drone survey initiative and;
- supported ongoing fish tagging efforts.

FORCE has led multiple sensor platform deployments through the Fundy Advanced Sensor Technology (FAST) Program. This year, focus was on testing a cabled system with multiple environmental sensors known as the FAST-Environmental Monitoring System.

FORCE also hosted several events and workshops. In 2018, FORCE welcomed over 3,000 guests to the Visitor Centre.

Work with Acadia University resulted in the installation of a second radar on Cape Sharp headland, which will be combined with the pre-existing radar to provide a view of the full Minas Passage and allow for both monitoring of the sea state and vessel activity. This work supported a master's student in 2018 who assessed surface currents using the radar data.



Testing at CHTTC, photo credit: CHTTC

CHTTC

The CHTTC worked on the following projects in 2018:

- Underwater connection for river turbines that can work in winter;
- Flow measuring buoy on a mooring line;
- Solar inverters for power electronics for hydrokinetic turbines;
- Assessment of the hydrokinetic resource using Radarsat 2.

WCWI

The WCWI of UVic is focused exclusively on wave power and focused on the following activities in 2018:

- Coastal modelling; Resource analysis;
- Low TRL performance evaluation;
- Technical Performance Level (TPL) work;
- Government engagement;
- Continuing education and updating state of the art to relevant organisations.

Acadia Tidal Energy Institute

Recent projects are focused on fish studies, bird studies, resource analysis, socioeconomic studies, social license and collaborations with other universities, institutes and industry and include:

- Nova Scotia small tidal test centre gap analysis and business case;
- Floating hydrophone study;
- Community impact of tidal projects;
- Projects on Environmental Monitoring, Modelling and Forecasting for instream tidal power;
- Workshop on turbulence in tidal sites.

Wave Energy Research Centre, NL

The centre currently has a five-year project focused on developing an economical wave powered pump to deliver water to an on-shore aquaculture farm.

Collaborations

- CHTTC in collaboration with New Energy Corp. and Sagkeeng First Nation community in Manitoba to deploy a vertical axis turbine of 25kW;
- The Plat-I by SMEC was outfitted with acoustic and optical sensors to complete required monitoring of the tidal environment in the Bay of Fundy. The organisation

Sustainable Ocean Applied Research (SOAR), completed the work and contributed environmental monitoring research;

- WCWI of UVic partnered with Orsted to deploy an Ocean Sentinel monitoring platform in 2019 to monitor the pacific coast wave environment and assess the resource.

CanmetENERGY/NRCan and National Research Council (NRC)

Marine energy resources atlas for province of BC is completed and will be launched in 2019. This atlas provides a comprehensive assessment of tidal, wave and river hydrokinetic energy resources throughout BC. It has assembled a geo-spatial database containing best-available information on wave, tidal and river hydrokinetic resources combined with other relevant socio-economic datasets and develop a specialized geo-spatial analysis, mapping and decision support system to support and inform stakeholders in identifying and evaluating sites for prospective development.

NRCan in continuing collaborative research projects in advancing river hydrokinetic energy with NRC, academia, marine energy industry and Canadian Hydrokinetic Turbine Test Centre. Methodology to identify potential sites in a river stretch using radar satellite images taken during winter months where fast flowing river sections in Canada are not likely to freeze is progressing and will be validated in coming year.

Scale model testing of vertical axis have been completed to validate numerical model to investigate multiple turbine array interactions and spacing between turbines. Number of turbine configurations simulations have been performed and this has improved understanding in how to optimize energy extraction from a stretch of river resource. Ultimately, aim is to develop guidelines for river hydrokinetic turbine array configurations.



Installation of the New Energy Corp. Turbine, photo credit: CHTTC

TECHNOLOGY DEMONSTRATION

DEPLOYMENTS

- Cape Sharp Tidal deployment of Open Hydro turbine at FORCE site in Bay of Fundy, NS;
- Big Moon Power scaled version Kinetic Keel deployment Bay of Fundy, NS;
- Bluetility deployment of prototype wave device in BC;
- Neptune Wave small-scale wave device deployment in BC;
- SMEC deployment of Plat-I at Grand Passage site in Bay of Fundy.



SMEC Plat-I deployment, photo credit: SMEC



New Energy Corp. Preparing for installation, photo credit: CHTTC

PLANNED DEPLOYMENTS

FORCE

Berth holders (lease holders) at the FORCE site are required to deploy by December 2020 in order to access the power purchase agreements (PPA) that have been put in place. If they do not deploy, they will lose the PPA and site lease.

CHTTC

- Water Rotor;
- Smart Hydro;
- New Energy Corp;
- Blue Vadar and
- New Energy 25kW turbine in Sagkeeng First Nation community

West Coast Wave Initiative

- Accumulated Ocean Energy Wave.

RELEVANT NATIONAL EVENTS

Events held in Canada in 2018 include:

- G7 Ocean Partnerships Summit May, Halifax, NS;
- Marine Renewables Canada (MRC) Annual Conference and Research Forum, November, Halifax, NS;
- British Columbia Technology Summit;
- Smart Energy Conference, April, Halifax, NS;
- CORE Energy Conference, Maritime Energy Association, Halifax NS;
- The Future of Energy -Symposium, Municipality of Digby, October, Digby NS;
- Oceans Week, June, NS

CHINA

In 2018, the mid-term evaluation about “the 13th Five-Year Plan for Marine Renewable Energy (2016-2020)” was conducted by the Ministry of Natural Resources (MNR). The Ministry of Science and Technology (MOST) released the National Key Research and Development Programme ‘Renewable energy and hydrogen energy technology’ to support the R&D of ocean energy.

OVERVIEW

In 2018, the mid-term evaluation about “the 13th Five-Year Plan for Marine Renewable Energy (2016-2020)” was conducted by the Ministry of Natural Resources (MNR). The Ministry of Science and Technology (MOST) released the National Key Research and Development Programme ‘Renewable energy and hydrogen energy technology’ to support the R&D of ocean energy. The new round of Special Funding Programme for Marine Renewable Energy (SFPMRE) was initiated, and 2 demonstration projects were funded. Some new tidal current turbines were deployed in 2018.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The mid-term evaluation about “*the 13th Five-Year Plan for Marine Renewable Energy (2016-2020)*” was conducted by the MNR in 2018, and the National Ocean Technology Centre is responsible for the implementation of the mid-term evaluation. “*the 13th Five-Year Plan for Marine Renewable Energy (2016-2020)*” was released by State Oceanic Administration (SOA) in December 2016. The overarching vision of the Plan is to i) Promote the demonstration and application of marine renewable energy, ii) Focus on the breakthroughs in key technologies, iii) Improve the technology levels of marine renewable energy, iv) Strengthen the construction of public service platform, and v) Foster international cooperation in development of marine renewable energy”. By 2020, the total installed capacity of marine renewable energy will be more than 50 MW in China.

PUBLIC FUNDING PROGRAMMES

The new round of Special Funding Programme for Marine Renewable Energy (SFPMRE) was initiated. In 2018, a total budget of RMB 79 million was granted for 2 marine renewable energy demonstration projects, the 1 MW Zhoushan tidal current energy demonstration project and the optimization and application of a highly reliable MRE system. The special funding programme has invested above RMB 1.3 billion since 2010 and 114 MRE projects were funded.

The Ministry of Science and Technology (MOST) released a draft of the National Key Research and Development Programme ‘Renewable energy and hydrogen energy technology’ for public review in March 2018. There were 2 MRE tasks in the programme, task I “Research on MRE resources characteristics and high-efficiency energy conversion mechanism” and task II “Research on MRE key technology and equipment”. The programme will provide the funds which are applied to research projects. The application of task I was started in 2018, a total budget of RMB 23 million will be granted for task I and task II will be started in 2019.



RESEARCH & DEVELOPMENT

WAVE ENERGY

Sharp Eagle WEC

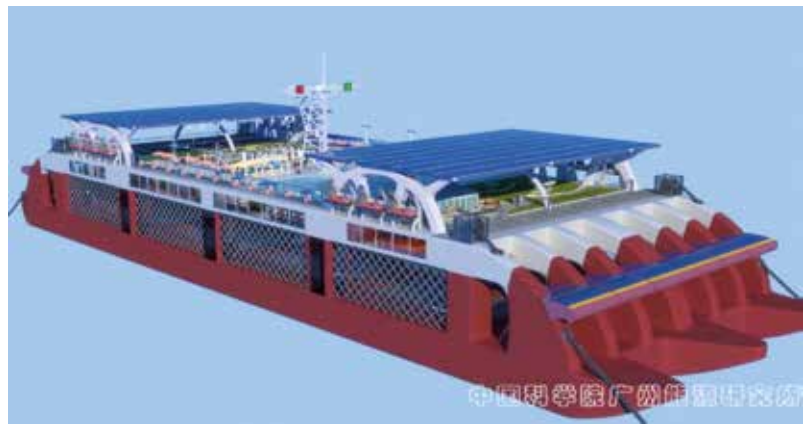
In 2015, the Guangzhou Institute of Energy Conversion (GIEC) successfully developed and built the 100kW prototype of Sharp Eagle “Wanshan”. The device is 36m×24m×16m, and weighs 1,000 tons. It’s a floating power station. The device was deployed near Wanshan Islands for sea trial in November 2015. The device realized intermittent power generation in small waves of 0.5 meters and safe power generation in large waves of 4 meters, and the total conversion efficiency reached above 20%. In April 2017, Sharp Eagle “Wanshan” was connected to the grid on Wanshan Island.

In December 2017, supported by the Chinese Academy of Sciences (CAS) and China Southern Power Grid, the upgrade of 260 kW wave-solar-storage-desalination offshore floating energy platform “Pilot 1” based on Sharp Eagle technology was completed (Installed wave energy 200 kW, Installed solar energy 60 kW, a desalination facility with daily production of 6 tones water).

The 260 kW “Pilot 1” offshore floating energy platform deployed for open sea test in January 2018 and was successfully connected to the remote island power grid through submarine cables in Hainan province on 31 August 2018.

Power Platform for Offshore Cage

In order to solve the situation of shortage of energy supply and poor wind-wave resistance of traditional aquaculture cages in China, the GIEC combines Sharp Eagle wave power generation technology with aquaculture, offshore tourism, science popularization, using wave energy to power the integrated platform of aquaculture, tourism, science popularization. The GIEC has applied patents for the integrated platform technology for aquaculture powered by wave energy and tourism in China, the European Union, Japan and Canada. Construction of the first prototype began in December 2018, and it is expected to be completed in June 2019.



TIDAL CURRENT ENERGY

ZJU 650 kW H-axis Turbine

Sponsored by SFPRE and the MOST, the Zhejiang University invented a series of tidal current energy turbines. The 60 kW tidal current energy turbine was deployed in 2014. The 120 kW semi-direct drive H-axis turbine was deployed in 2015. And the Zhejiang University deployed a 600 kW horizontal axis turbine in 2018. This is the third turbine, after the 60 kW and 120 kW sea trials, cut in current velocity: 0.7 m/s, rated current velocity: 2.5 m/s.

United Power 300 kW H-axis Turbine

Sponsored by SFPRE, the Guodian United Power Technology Company Limited (United Power) is developing a new 300 kW H-axis turbine. The turbine has been deployed near Zhairuoshan Island for sea trial and connected to the grid since March 2018, generating 288 MWh until November 2018. Cut in current speed: 0.5m/s, Rated current speed: 2.0 m/s, Maximum conversion efficiency: 40%, Support structure: Floating.



TECHNOLOGY DEMONSTRATION

PROJECTS IN THE WATER

LHD Tidal Current Energy Demonstration Project

Supported by the SFPRE, the Hangzhou United Energy Co. Ltd. is developing the LHD Tidal current energy demonstration project. The #1 demonstration platform was deployed near Xiushan Island in March 2016. They plan to install 7 turbines in their platform, with installed capacity of 3 400 kW. 2 turbines (600 kW, 400 kW) were installed on the platform in July and connected to the grid in August 2016. The amount of electricity accumulated was more than 1GWh until December 2018. In 2016, Hangzhou United Energy Co. Ltd. was funded RMB 45 million by the SFPRE to develop new 300 kW h-axis turbines and a new 400 kW v-axis turbines. The turbines were deployed in December 2018; the capacity of LHD project reached 1.7 MW.

In 2018, LHD was funded RMB 72 million by the SFPRE to press ahead with the next phase project, including (4.1 MW) #2 platform and a 1 MW V-axis turbine. Three turbines will be installed on the #2 platform, the full capacity of LHD project across all phases will be up to 7 MW.

ZJU Tidal Current Energy Demonstration Project

In 2018, the Zhejiang University (ZJU) installed a 600 kW tidal current turbine on the platform near the Zhairuoshan Island (with 60 kW turbine already deployed in 2014 and 120 kW turbine deployed in 2015). In the future, the platform will serve as a testing platform for tidal current energy turbines.

OPEN SEA TEST

Sponsored by SFPRE, NOTC developed the mobile test system for MRE device (Including power test system, monitoring system, data communication system and comprehensive evaluation system). The test system can provide test service such as power quality and power characteristic of MRE power system for MRE developer.

PLANNED DEPLOYMENTS

Wanshan Wave Energy Demonstration Project

Based on the previous wave energy research, the SFPRE supported the construction of China's first MW-level wave energy demonstration farm in July 2017. Led by GIEC, it is jointly undertaken by other 6 units, including China Southern Power Grid and China Merchants Heavy Industry Co. The total project budget is RMB 151 million. It aims to use Sharp Eagle wave power generation technology developed by GIEC to build a MW class wave energy demonstration farm on Wanshan Island. It will make Wanshan become an important base for intensively displaying wave energy technology in China, and popularize and apply Wanshan technology to other islands in China. The design for construction, PTO system and mooring system was finished, the manufacture began in December 2018 and will finish in October 2019.

DENMARK

Wave energy activities in Denmark continue to be driven by the Strategy for Wave Power published 6 years ago and by the Danish Wave Power Roadmap from 2015.

OVERVIEW

Wave energy activities in Denmark continue to be driven by the Strategy for Wave Power published 6 years ago and by the Danish Wave Power Roadmap from 2015. Wave energy in Denmark is funded mainly through the EUDP. There are 11 active Danish wave energy developers: Exowave, Weptos, Resen, WavePiston, Waveplane, Floating Power Plant, Leancon, Crestwing, KN Swing, Wave Dragon and WaveStar. The most relevant wave energy activities recently undertaken include: The collaboration of Floating Power Plant, a hybrid wind and wave technology, with DP Energy for the development of projects in Scotland and Wales; the installation and testing of Crestwing prototype with data to be analysed by NIRAS in co-operation with DHI; and the testing of the WavePiston at the DanWEC test site and the completion of the WEPTOS testing in sheltered water.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

Wave energy activities in Denmark continue to be driven by the Strategy for Wave Power published in 2012 and by the Danish Wave Power Roadmap from 2015.

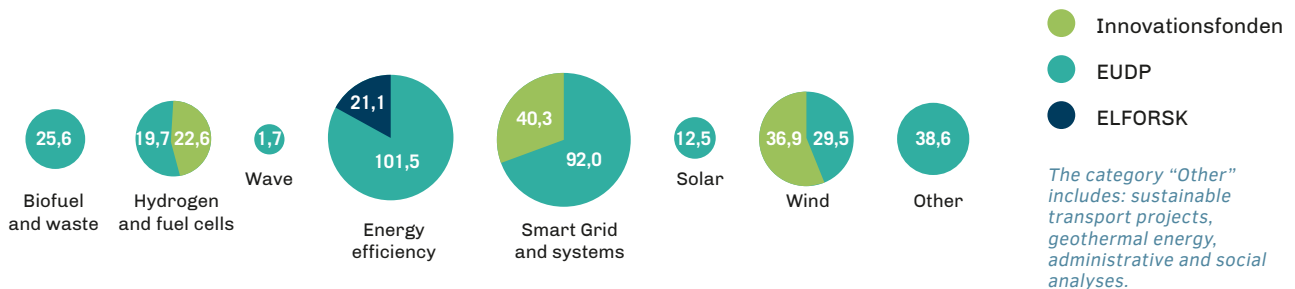
Denmark has created a plan for the use of the sea; the partnership for Wave Energy has participated in the planning meetings to discuss possible shared use of sea space utilizing synergies between wave power, wind power and aquaculture. Denmark has established the test site DanWEC. The Energy Agency is dealing with matters concerning permits of wave energy test unit installations at sea.

PUBLIC FUNDING PROGRAMMES

Wave energy in Denmark is funded through the EUDP along with other renewables. *Innovationsfonden* has since 2010 supported innovation in relation to activities related to waves and floating structures. The figure below shows the distribution between different technologies¹.

PROGRAMME GRANTS BY TECHNOLOGY - 2017 (DKK MILL.)

Source: Energiforskning.dk



¹ https://ens.dk/sites/ens.dk/files/Forskning_og_udvikling/energiaret18_uk_260618web.pdf

RESEARCH & DEVELOPMENT

Overview of the main research activities in 2018:

OES Task 10 Modelling, Verification and Validation of Wave Energy Converters (WECs)

The Danish Funding Agency EUDP has funded the proposal submitted by Ramboll in 2017 in collaboration with Aalborg University, DTU and Floating Power Plant to work and help co-ordinate the international collaboration on OES Task 10 with focus on Modelling, Verification and Validation of Wave Energy Converters (WECs). OES Task 10, which involves experts from 13 countries, was agreed to during the 31st EXCO in 2016 with the objective to improve the confidence in the numerical tools used in design and prediction of power production from Wave Energy Converters.

Wave Energy Research Group at Aalborg University

Mooring Solutions for Large Wave Energy Converters (MSLWEC) 2016 – 2018 has been co-ordinated by Aalborg University, investigating different mooring solutions suited for large WECs being investigated in Denmark, such as Floating Power Plant, WaveDragon, Leancon and KNSwing.

The use of synthetic mooring lines showed to be more cost effective compared to conventional catenary mooring lines. The project has resulted in several publications, such as “Cost Optimization of Mooring Solutions for Large Floating Wave Energy Converters” Energies 2018, 11. Floating Power Plant was tested in model scale as part of the project.

Marinet 2

The new test facility at Aalborg University is part of the Marinet 2 infrastructures, and some Danish developers have received funding from the programme to carry out model tests.

MARINERG-i

The objective of MARINERG-i is to become the leading internationally distributed infrastructure in the Marine Renewable Energy (MRE) sector. Its integrated nature and co-ordinated approach will accelerate the research development and deployment of offshore wind, wave, tidal and combined energy technologies and help maintain Europe as a global leader in this industry. In addition, MARINERG-i will strengthen European, scientific and engineering excellence and expertise as its’ combined facilities represent an indispensable tool to foster innovation across a large variety of MRE technologies and systems and through all key stages of technology development (TRLs 1-9).

DTOcean+

Aalborg University, Denmark, is one of the 17 EU partners in the DTOcean + project lead by Fundacion Tecnalia Research & Innovation, a 3-year project (May 2018 -April 2021) with a total budget of €8 million, with the objective to support the entire technology innovation process, from

concept to deployment of sub-systems, energy capture devices and arrays.

WECANet (COST action)

Denmark is represented in the European project WECANet (www.wecanet.eu), a pan-European network with an interdisciplinary marine wave energy approach aiming to provide a strong networking platform for all stakeholders in wave energy. This project is funded by the European Cooperation in Science and Technology action (known as ‘COST’ action).

ICONN (MC EID)

ICONN is a unique European Industrial Doctorate initiative to meet the current and future demand for highly skilled offshore wind and wave energy engineers by developing and advancing European capacity in the design, development and performance optimisation for Offshore Wind and Wave Energy installations. The initiative is strongly shaped by active participation from industries and will develop and enhance European capacity in the offshore renewable energy area at a critical juncture in time when Europe strives to occupy a lead market position globally in this sector. Project partners are Aalborg University, Trinity College and Floating Power Plant.

Europe Leading Blue Energy (ELBE)

Offshoreenergy.dk (now called Energy Innovation Cluster) is partner in the ELBE (Europe Leading Blue Energy) project co-ordinated by the Basque Energy Cluster, including Aberdeen Renewable Energy Group, Flanders’ Maritime Cluster, Offshoreväst (Sweden), acknowledging the importance of marine energy technological development and wave, tidal and floating wind power represented by these European clusters. This project is part of the European Union DG GROWTH “Cluster Go International” programme. The purpose of ELBE is to forge a formal alliance between participating bodies and define a joint internationalisation strategy for SMEs to be launched in the second phase and the organisation of several networking events among the companies of the different regions at the end of 2018 and the start of 2019.

More information at:

<https://www.clustercollaboration.eu/cluster-mapping> and <http://www.eicluster.dk/>

New Material for Wave Energy Substructures

The project is supported by EUDP from 2016 to 2019 and lead by Aalborg University. During its execution, the project will determine whether it is possible to use the material resulting from sea water electrolysis for step-change improvements to the state of the art of available materials and construction practices in the wave energy and offshore sector. A first test of the new concept was carried out at DanWEC in Hanstholm and a second test started in Nissum in November 2018.

More information at:

<https://www.civil.aau.dk/Project+websites/newmaterialwes/?page=1>

TECHNOLOGY DEMONSTRATION

PROJECTS IN THE WATER

DanWEC (www.danwec.com)

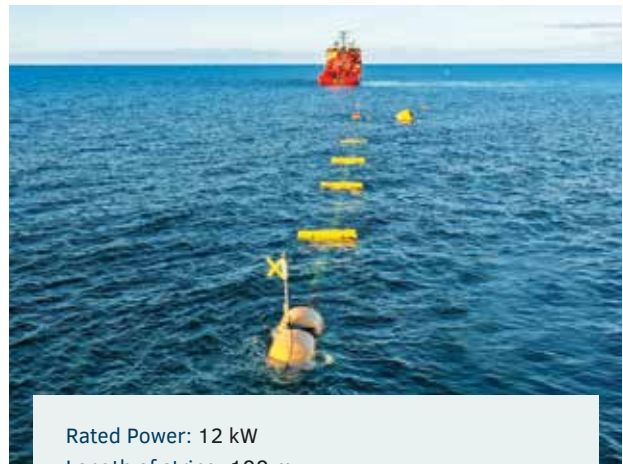
The test site facility DanWEC is located with an offshore test site facing the North Sea (**Hanstholm**) where several Danish concepts have been tested and a more sheltered site in **Nissum Bredning** is also part of the DanWEC portfolio offered to testing in smaller scale.

Wavepiston

The testing of the Wavepiston prototype started in 2015 at the DanWEC test site with several development iterations increasing the energy production and durability in each iteration.

The first prototype tested was a 150-m string, which in the first iteration was equipped with 2 energy collectors, each fitted with a 4 m² plate. In the second and third iteration another 4 energy collectors were fitted with a 7 m² plate each. In the current 2018 iteration the string is 100 m. Four energy collectors have been tested each with an 8.5 m² plate and there is the possibility to test up to 6 energy collectors. Different storm protection systems are tested on the energy collectors.

The storm protection system reduces the plate area when forces get too big. Data from the loads and the energy production is collected on a computer on the inner buoy and uploaded to a server every 6 hours. The data on the collected energy is analysed and compared to the predictions from the Wavepiston Energy Tool developed in collaboration with the Technical University of Denmark.



Rated Power: 12 kW
Length of string: 100 m
Number of energy collectors: 6
Plate area (energy collector): 8.5 m² (app. 3mx3m)
Water depth: 26 m
Significant wave height, Hs: 0.5 – 8.0 m
Peak wave periods, TP: 3 – 7.5 s.
Extreme: Hs of 8.2 m and Hmax of 15 m
Ocean current max: 1.6 m/s



Rated Power: 20 kW
Length of float: 30 m
Width: 7,5 m
Weight: 65 ton
Water depth: 20 m
Significant wave heights, Hs: 0.5 – 1.5 m
Peak wave periods, TP: 3 – 5.5 s.
Extreme: Hs m and Hmax of 3 m
Website: <https://crestwing.dk>

Crestwing

Crestwings prototype Tordenskiold was launched in Kattegat in autumn 2018, northeast of the islands of Hirsholmene, in Frederikshavn Municipality. Tordenskiold will be tested in Kattegat as a suitable scaled ocean to confirm the reliability of the mooring at sea and confirm the expected production of energy. The plant will be tested in this position through the year 2020.

It has taken Crestwing 14 years and about 30 million DKK to get to the point of a prototype that can easily be scaled up and produced. Crestwing expect to produce energy at a kWh price, which corresponds to the production of other renewable energy types.

The data from the testing of Crestwing prototype will be analysed by NIRAS in co-operation with DHI.

WEPTOS

The scale testing of WEPTOS in co-operation with AAU was deployed in July 2017 and completed in October 2018. The deployment location was in Lillebælt between Jutland and Fyn in Denmark, north of the small island Brandsø. The test results are presented in Proceedings of OMAE2018 conference 17-22 June 2018, Madrid, Spain. In wave conditions with $H_{m0}=0.27$ m and $T_e=2.11$ s, and the maximum and average power within the 15 min measurement period was 1805 W and 335 W measured on one “leg”. The project had financial support from the R&D programme ForskEL.

PLANNED DEPLOYMENTS

Projects under development planned to be soon deployed in the sea:

- Nemos plan for tests at DanWEC Hanstholm 2019.
- WavePiston plans to continue testing at DanWEC Hanstholm 2019.
- ResenWaves expects tests in 2019 in Nissum Bredning.



Rated Mechanical Power: 2*3 kW
 Length Sum of widths of rotors: 2*11 m
 Rotor width: 1.1 m
 Rotor diameter: 0.9 m
 Water depth: 10 m
 Significant wave heights, HS: 0.25 – 1.25 m
 Peak wave periods, TP: 2.0 – 3.5 s.
 Extreme: HS 2.4 m and a maximum TP 5.0 s
 Website: <http://www.weptos.com/>

RELEVANT NATIONAL EVENTS

Danish Partnership for Wave Power

The Danish Wave Energy Partnership meetings in 2018 are relevant for the development of the sector. The meetings typically focus on the dissemination of results among the partners and as an occasion to initiate new common development activities. These have been held twice in 2018, at 15 March before the launch of Crestwing and at 11 September 2018 at Aalborg University.

The partnership involves the 11 active Danish wave energy developers: Exowave, WavePiston, Waveplane, Weptos, Floating Power Plant, Leancon, Crestwing, KN Swing, Wave Dragon, Resen and Wavestar.

The partnership has its secretariat at Energy Innovation Cluster (<http://www.eiccluster.dk/>) providing links and networks opportunities to develop innovative solutions and synergies with other maritime industry.

More information at: <http://www.wavepartnership.dk>

EUROPEAN COMMISSION

In March 2018 the SET-Plan Ocean Energy Implementation Plan has been endorsed. It sets out technical, financial and environmental actions for the coming years to support the development of ocean energy technologies towards commercialisation and to realise the cost-reduction targets agreed in 2016.

OVERVIEW

In March 2018 the SET-Plan Ocean Energy Implementation Plan has been endorsed. It sets out technical, financial and environmental actions for the coming years to support the development of ocean energy technologies towards commercialisation and to realise the cost-reduction targets agreed in 2016.

Following this plan, the European Commission has undertaken a market study assessing financial needs and providing options for the design of Investment Support and Insurance Fund for ocean energy technologies.

The European Commission cooperates closely with its Member States to increase support for ocean energy and to encourage them to include trajectories for marine renewable energies in their 2030 National Energy and Climate Plans that are currently being developed.

The European Commission continued to support ocean energy development via their funding programmes like Horizon 2020 and the European Regional Development Fund.

SUPPORTING POLICIES FOR OCEAN ENERGY

The European Commission is supporting the development of the ocean energy sector through an array of activities based on two major policy initiatives: the Energy Union and the SET-Plan in particular, and the Blue Growth Strategy. The main aim of these activities is to drive the development of ocean energy within the transformation of the European energy system and to exploit its potential to create growth and jobs in the EU.

In particular in 2018, the SET-Plan Steering Committee has endorsed the “SET-Plan Implementation Plan for Ocean Energy¹” developed by the Temporary Working Group (TWG). It proposes 11 actions in order to meet the SET-Plan Targets agreed in the 2016 “SET-Plan Declaration of Intent on Ocean Energy²”. These targets are a levelised cost of energy (LCOE) of 15 cEUR/kWh by 2025 and of 10 cEUR/kWh by 2030 for tidal energy and of 20 cEUR/kWh by 2025 of 15 cEUR/kWh by 2030 for wave energy technologies.

The actions address technological, financial and environmental barriers that are hindering the development and deployment of ocean energy technologies and as a consequence their cost-reduction:

Technical Actions:

1. Tidal energy – assist technology development and knowledge building up to TRL6.
2. Tidal energy – support system demonstration in operational environment and knowledge building in the TRL 7-9 categories.

¹ Implementation Plan – https://setis.ec.europa.eu/system/files/set_plan_ocean_implementation_plan.pdf

² Declaration of intent – https://setis.ec.europa.eu/system/files/integrated_set-plan/declaration_of_intent_ocean_0.pdf

3. Wave energy – support technology development, system demonstration and knowledge building up to TRL 6.
4. Wave Energy – encourage and support device and system demonstration at early demonstration array scale up to TRL 7-9.
5. Collaborate in the areas of installation, logistics and infrastructure.
6. Co-ordinate the development of standards and guidelines for wave technology evaluation and LCoE analysis.

Financial Actions:

7. Investigate the potential for creation of an Investment Support Fund for ocean energy farms: EU and National Authorities should collaborate in order to create a Fund providing flexible capital, and enabling further private capital to be leveraged.
8. Progress the creation of an EU Insurance and Guarantee Fund to underwrite various project risks: This would be targeted at the first ocean energy projects to cover risks such as availability, performance, unforeseen events, failures, etc. Consider the provision of a common reserve fund available to multiple projects in the initial farm or plant roll-out, to spread the risk and reduce the cost of providing guarantees.
9. Support the development of a collaborative procurement model adaptation of the “Wave Energy Scotland” approach for wave energy development at EU Level using pre-commercial procurement or similar.

Environmental Actions:

10. Collaboration on the development of certification and safety standards for the development, testing, deployment of ocean energy devices,
11. Continue the de-risking of environmental consenting through an integrated programme of measures and in particular through promoting open data sharing.

An estimated overall investment of EUR 1.2 billion is required to ensure the success of the implementation plan, taking into account contribution from industry, national and European funds :

- EUR 409.5 million coming from the industry (private funds - 33% of the total);
- EUR 421.5 million coming from national/regional programmes - (34% of the total);
- EUR 411.5 million coming from EU funds (33% of the total – mainly from Horizon 2020 and a minor part from InnovFin EDP).

As mentioned in the European Commission Blue Growth

Strategy, ocean energy can play a threefold role in the EU, helping meeting decarbonisation targets, fostering growth in European regions and becoming a driver for employment. The contribution of Ocean Energy to the blue economy was accounted in the European Commission first “Annual Report on the Blue Economy³” published in July 2018. The report examines the role of emerging sectors, including ocean energy, and the opportunity that they bring for attracting investments and potential future deployments. The analysis showed that in the EU between 2007 and 2015 cumulative investments for EUR 2.6 billion has been directed towards the ocean energy sector, with 74% of the funds coming for private corporate investments (1.9 EUR billion), with the supply chain located in many EU regions, including landlocked countries. The European Commission, in the period 2007-2018, has supported a variety of ocean energy projects for a total investment of EUR 864 million, through different instruments such as R&D framework programmes (FP6, FP7 and Horizon 2020), European regional development funds (ERDF), and demonstration support with the NER 300 and the InnovFin Energy Demo Projects (EDP).

The “Clean Energy for EU Islands⁴” is a new policy initiative, launched in 2017, with the aim of helping islands to generate their own sustainable, low-cost energy through the use of the latest renewable energy technologies. Whilst not specific to ocean energy, the initiative offers scope for the investigation of the use of ocean energy technologies in EU islands, especially when coupled with energy storage facilities. In Europe a significant part of the installed ocean energy devices is located in the proximities of islands such as Orkney (UK), Shetlands (UK), Ussant (FR), Crete (GR), Gran Canaria (ES) and Texel (NL).

In 2018 two environmental projects amounting EUR 1.5 million funded by DG MARE/EASME (Executive Agency for Small and Medium-sized Enterprises) started: SEAWAVE led by EMEC and WESE led by Azti Tecnalia. The projects will run for three years and provide information on the interaction between wave energy converters deployed at EMEC and BIMEP with the marine environment with the aim of reducing uncertainties related to licensing and consenting of wave energy farms.

MARKET INCENTIVES

The NER300 programme remains the main market incentive scheme supporting first-of-a-kind commercial-scale renewable energy projects. Five ocean energy projects were awarded support through NER300 in 2013 and 2014. No new projects were announced in 2018. The table below presents an overview of the project announced and their status.

³ <https://publications.europa.eu/en/publication-detail/-/publication/79299d10-8a35-11e8-ac6a-01aa75ed71a1>

⁴ <https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/clean-energy-eu-islands>

Pre-commercial projects awarded support through NER300

Country	Technology	Project	NER300 award (million €)	Project status
UK	Tidal	Sound of Islay	20.65	Ongoing.
UK	Tidal	Stroma/MeyGen phase 1B	16.77	Awaiting Final Investment Decision. Atlantis to install newly developed 2 MW turbines as part of the project
FR	OTEC	Nemo	72	Awaiting Final Investment Decision. Expected installation in 2020 http://www.akuoenergy.com/fr/nemo
PT	Wave	Swell	9.1	Ongoing. Licensing and permit obtained. The installation is expected to take place during the summers of 2019 and 2020.
IE	Wave	WestWave	23.2	Ongoing. Technology procurement is ongoing but dependent on status of wave energy technology.

PUBLIC FINANCE PROGRAMMES

The European Investment Bank (EIB) together with the European Commission has launched the InnovFin Energy Demo Projects (EDP) which provides support in the form of loans for first-of-a kind projects. InnovFin aims to facilitate and accelerate access to finance for innovative businesses and projects in unproven markets in Europe. The scheme helps reducing the financial risk of demonstration projects, offering equity and debts tailored to the need of the project.

Projects supported by EIB InnovFin Energy Demo

Country	Year	Project	Funding (million €)	Status
PT/FI	2016	WaveRoller	10 (3PT & 7FI)	Financed

FINANCE PROGRAMMES

In 2018 the European Commission has presented their proposals for their funding programmes for 2021-2027. Horizon Europe will be the successor of Horizon 2020 and the initial budget proposal for Research and Innovation is EUR 100 billion. The European Commission has proposed an EU Innovation Fund for the period 2021-2027, which will build on the NER300 programme. The Innovation Fund has been established by the revised EU Directive to enhance cost-effective emission reductions and low-carbon investments. The fund will support low-carbon innovation in energy intensive industry, carbon capture and utilisation (CCU) technologies, innovative renewable energy and energy storage technologies, and demonstration projects on the environmentally safe capture and geological storage of CO₂ (CCS).

The European Commission has proposed an EU Innovation Fund for the period 2021-2027, which will build on the NER300 programme.

RESEARCH & DEVELOPMENT

The Horizon 2020 is the current framework programme put in place by the European Commission to support innovative R&D actions. Since its inception in 2014, the H2020 programme has provided more than EUR 165 million for ocean energy R&D to 44 different projects, including feasibility studies under the Small Medium Enterprises instrument.

Horizon 2020 currently funds 17 R&D projects on ocean energy. Five projects were awarded in 2018 and focusing predominantly on tidal energy demonstration, wave energy power take off (PTO) and array design. Currently there is one Horizon 2020 opportunity open for application focussing on “European Pre-Commercial Procurement Programme for Wave Energy Research & Development⁵”

An overview of ongoing H2020 R&D projects is presented in the table below, focusing on the objective of the newly announced projects and presenting the key achievements obtained in 2018. Highlights include the fabrication of the second Penguin WEC at EMEC as part of the CEFOW project, the 3 GWh mark achieved by the OR2 floating tidal energy converter in the FloTEC project, the deployment of the Corpower WEC at EMEC, the installation of the new turbine on the Marmok wave device, the deployment of the Deepgreen500 device, and the design of new PTO as part of the TIPA and TAOIDE projects.

More information about the projects and results can be found via the CORDIS project database:

<https://cordis.europa.eu/projects/en>

Ocean Energy R&D H2020 projects awarded since 2015

Year	Acronym	Technology developer	Focus	Key Achievement in 2018
2018	RealTide	Sabella, EnerOcean	Identifying failure caused on tidal turbines at sea whilst providing a step-change in the design of key components such as blades and PTO.	In preparation of the deployment of the Sabella device in 2018, real-time monitoring tools have been installed on the nacelle of the device.
2018	Imagine	Innovative Method for Affordable Generation IN ocean Energy	Developing a new Electro-Mechanical Generator (EMG).	Design, development and fabrication of a 250kW EMG prototype, with CAPEX reduction of over 50% with respect to current PTO systems taking into account operation with four different WEC designs.
2018	MegaRoller	AW Energy	To develop and demonstrate a next-generation Power Take-Off (PTO) solution for wave energy converters.	The proposed PTO technology for a 1MW oscillating wave surge converters (OWSC).
2018	Sea-titan	Wedge, Corpower	Designing, building, testing and validating a direct drive PTO solution to be used with multiple types of wave energy converter.	Started work on the development of a new configuration and geometry of a first generation Multitranslator Linear Switched Reluctance Machine.
2018	DTOceanPlus	Corpower, EDF, Enel Green Power, Naval Energies, Nova Innovation, OceanTEC	To develop and demonstrate a 2nd-generation open source design tool for ocean energy technologies including sub-systems, energy capture devices and arrays.	The project has identified functional requirements and metrics for the 2nd generation design tool and is working on the development of the new tool.
2017	Ocean_2G	Magallanes	To develop a 2MW pre-marketable floating tidal energy platform.	In 2018 the 2MW device was fabricated and towed to EMEC in preparation for installation.
2017	EnFait	Nova Innovation	Designed to scale up the existing 300 kW tidal array located in Shetland by expanding it to 600-700kW with incremental addition of 100kW tidal turbines.	Identification of upgrades necessary for the turbines, including condition monitoring tools.
2017	OCCTIC	OpenHydro	To drive the cost of open-centre tidal turbine in par with offshore wind, through goals advancement of the turbine system design to improve performance, efficiency and reliability	The project has worked on the optimisation of the open centre turbine focussing on blade and PTO design.

⁵ <http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/lc-sc3-ja-3-2019.html>

Year	Acronym	Technology developer	Focus	Key Achievement in 2018
2016	FLOTEC	Orbital	Demonstration projects of a 2MW floating tidal energy converter, aiming to reduce the cost of the technology from 250 EUR/MWh to 200 EUR/MWh.	The OR2 was deployed at EMEC in 2016, and has now generated over 3GWh of power with capacity factors above 38%. An improved version of the 2MW devices has been developed.
2016	TAOIDE	Ocean Renewable Power Company	Development of wet-gap generators and life time cost reduction.	The project has reached half-way, and has now finalised the design of the synchronous permanent magnet generator which is expected to be tested in 2019.
2016	TIPA	Nova Innovation	PTO optimisation and cost reduction of 20% of lifetime costs.	The new PTO has been commissioned and will be tested in 2019.
2016	WaveBoost	Corpower	Improving the PTO for the next generation Corpower device.	Corpower wave energy device was deployed at EMEC in 2018, with the company now working on the next iteration of the device, at stage-gate 4.
2016	MUSES	N/A	To review existing planning and consenting processes against international quality standards for maritime spatial planning (MSP) and compliance with EU Directives	An analysis of marine stakeholders in Europe has been undertaken and an action plan to highlight the potential of Blue Growth in different regions in Europe is currently under development.
2016	OPERA	OceanTEC	To collect and share two years of open-sea operating data of a floating oscillating water column wave energy converter, and by doing so to remove the lack of operational data that is currently lacking for the R&D of wave energy.	In 2018, the Marmok device developed by OceanTEC was equipped with the new 30 kW turbine developed by Kymaner, which has been previously successfully validated at Mutriku.
2016	PowerKite	Minesto	Improving the reliability of the Minesto tidal energy converter, tethered turbine.	Minesto has optimised the design of the DeepGreen500, with the first device installed for testing at the Holyhead deep site.
2015	CEFOW	Wello	To install an array of 3 Penguin wave energy converters in 2017, 2018 and 2019, thus increasing the speed of wave power development, decrease the LCOE and create an efficient supply chain.	In 2018, Wello fabricated the second, more efficient WEC2, which is expected to be deployed at EMEC in 2019. Further the WEC3 design has been finalised.
2015	WETFEEET	OWC and Symphony	To investigate the issues of reliability, survivability and high cost of wave energy components and aim to present breakthroughs to reach commercialisation of wave energy technologies.	The project ended in 2018, having identified breakthrough for the array design of wave energy farms, and optimisation of OWC and Symphony designs.

SUPPORT TO INFRASTRUCTURES

Marinet 2, Foresea and Mariner-I projects, supported by the European Commission H2020 and European Regional Development Fund (ERDF) offer access to testing infrastructures and centres and, to research facilities across Europe.

REGIONAL PROGRAMMES

Interregional European projects (Interreg) aim at fostering transnational cooperation among neighbouring countries, encouraging collaboration to improve economic, social and territorial development of European regions. This includes projects such as Foresea (access to test centres), ITEG (exploring the integration of tidal energy and hydrogen) and MET-Certified (development of internationally recognised standards for ocean energy). New projects launched in 2018 include *Marine Energy Alliance* (with partners from FR, IE, NL, and UK), and Blue-GIFT (Blue Growth and Innovation Fast Track).

OTHER RELEVANT ACTIVITIES

The European Commission is also funding activities to get a better understanding of the ocean energy sector like studies or support activities for research and innovation and knowledge transfer.

Support activity projects funded under H2020

Year	Acronym	Title	Partnership	Focus	Key Achievement in 2018
2019	OceanSet	Implementation group of the Ocean Energy SET-Plan	SEAI (Ireland)	The project aims to realise the actions proposed in the SETplan implementation plan for ocean energy mentioned above	
2019	EtipOcean2	European Technology and Innovation Platform for Ocean Energy	Ocean Energy Europe (Belgium) and EERA JP partners	The project aims to optimize the use of existing resources available to the ocean energy sector, to streamline sectoral activities, and ultimately to accelerate its development and to maximize benefits for industry and society.	ETIP Ocean 2 will expand the work of ETIP Ocean and provide analysis and support for ocean energy development in the EU.

The European Commission conducted a “Market Study on Ocean Energy”⁶. The scope of the study was to understand the financial needs of the EU ocean energy sector, identifying current gaps and proposing possible financing solution taking into account the recommendations of the Ocean Energy Roadmap. The study puts forward recommendations for the creation of an Investment fund and of an insurance fund for ocean energy. The study quantified investment needs based on three different deployment scenarios (pessimistic, neutral and optimistic), which would range between 2.8 and 9.4 EUR billion, corresponding to 1.3 GW installed in the pessimistic case and 3.9 GW installed in the optimistic scenario.

The Joint Research Centre (JRC), the in-house centre of the European Commission for research and scientific advice to the EU, is doing an inventory of Future Emerging Technologies relevant to energy supply. The needs for the ocean energy sector and the type of innovations to bridge the gap with the market have been analysed and are published in the report *Future emerging technologies for the ocean energy sector: innovation and game-changers*:

<http://publications.jrc.ec.europa.eu/repository/bitstream/JRC112635/kjna29315enn.pdf>

A public study on the Impact of European funded Ocean Energy R&D projects of the last 20 years is on-going aiming to provide insights into the impacts of funding and opportunities to influence the recommendations to increase future R&D impacts.

⁶ <https://publications.europa.eu/en/publication-detail/-/publication/e38ea9ce-74ff-11e8-9483-01aa75ed71a1>

FRANCE

Although in 2018 the French regulatory framework has been notably simplified by the adoption of new laws and decrees that apply to all offshore renewable energies in order to facilitate and accelerate the deployment of offshore wind, several ocean energy pilot projects have been cancelled or postponed due to economic considerations.

OVERVIEW

Although in 2018 the French regulatory framework has been notably simplified by the adoption of new laws and decrees that apply to all offshore renewable energies in order to facilitate and accelerate the deployment of offshore wind, several ocean energy pilot projects have been cancelled or postponed due to economic considerations. However, more prototypes have been tested in French waters over this year than in previous years, partly thanks to the current availability of four grid-connected test sites (SEM-REV, SEENEOH, Brest-Sainte Anne and Paimpol-Bréhat) and the continuation of the Ushant Island pilot site, which is highly representative of the assets of tidal energy in the local energy mix for non-interconnected communities.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

In France, the Energy Act (Loi de Transition Energétique pour la Croissance Verte), adopted in August 2015, defines an aim of 40% renewable energy in the electricity mix by 2030. The application decree called “Pluri-annual Energy Policy”, which sets 10-year targets for installed capacity for all types of energy used in electricity production, was due to be updated in 2018, and every 5 years subsequently. Separate but comparable documents are defined for the mainland as well as overseas regions and territories. Distinct figures of installed capacities and timing for calls for tenders will be given for both bottom-fixed and floating offshore wind energy. The Ministry for an Ecological and Solidary Transition is in charge of setting these goals and completed a number of legislative reforms facilitating and accelerating offshore wind farm development processes (law 2018-727 and decree 2018-1204) at the end of 2017 and in 2018. However, for ocean energies, the mention is limited to the availability of public incentives for prototypes and pilot farms of converters until the LCOE of these technologies is demonstrated to be commercially competitive with respect to other renewable sources of energy.

In the Hydrocarbons Bill (which bans further drilling), published in January 2018, most sections support renewable energies by simplifying their deployment. Specifically, for offshore renewable energies, the cost of the export cable will now be supported by the French Transmission System Operator, which also takes over more legal and financial responsibilities with respect to the availability of the exportation of electricity.

Finally, in the Society in Confidence Act, adopted on 10 August 2018, which is dedicated to streamlining the legislative and legal framework for offshore energy projects, a so-called “envelope permit” has been adopted allowing project developers to ask for technological flexibility in their permits through an impact assessment based on the worst-case scenario. This procedure would also move most of the legal obligations (preliminary technical studies, initial environmental assessment, and public participation) upstream of the actual permit issuance, thereby considerably reducing the risk for project developers as long as the technical details of the project do not diverge from the initial plan.

In compliance with the EU directive on spatial planning, France has pursued identification of dedicated sites for offshore energy projects, with debates conducted by the regional local authorities for public consenting. The final Strategic Seaboard Document (DSF) should be completed by mid-2019.

MARKET INCENTIVES

An ongoing programme has awarded 2 demonstration pilot farms of tidal energy converters for partial support, allowing these projects to benefit from a feed-in tariff (€173/MWh), a grant and reimbursable loans: presently, both projects are on hold at Raz Blanchard.

Also in compliance with EU regulations on competitiveness, in the case of a call for tenders at a commercial scale, potentially foreseen for two high-energy tidal zones which have already been identified (Raz Blanchard and the Fromveur Strait in Brittany), a major part of the selection criteria will rely on the assessed price per MWh. However, the present LCOE of tidal energy is considered too high in order to enable such a call.

PUBLIC FUNDING PROGRAMMES

The Programme “Investment for the Future”, managed by the Prime Minister and, on energy topics, by the Ministry for the Ecological and Solidary Transition, is the major provider of the above mentioned incentives through grants and loans, with the selective help of three main agencies, depending on the TRL of the project (from higher to lower): Public Investment Bank (BPI), Environment and Energy Agency (ADEME), National Research Agency (ANR). Local authorities, at the regional level, also provide substantial support for prototypes and pilot projects.

ADEME created a roadmap for offshore energy as early as 2010. On this basis, several calls for initiatives and projects have been launched, from system parts to prototypes of pilot farms.

An estimated cumulative budget of this overall support for ocean energy in 2018 is €88 million, which includes 6 large completed or ongoing projects. New projects are expected in 2019 and the overall support to ocean energy for 2019 will depend on the projects received (it is not yet possible to estimate the allocated budget for 2019).

Awarded funds by ADEME have also been directed to river turbine arrays (some at estuaries where turbines function like a small capacity tidal array). Ongoing projects issued from calls for tenders of previous years also involve ocean thermal energy converters, wave energy converters, tidal turbine prototypes and technological bricks like subsea connectors or hubs, foundation concepts, specific dredging or installation tools, etc.

In 2018, ANR awarded financing to 5 new MRE R&D projects through the “Institute for the Energy Transition” call for tenders, in conjunction with France Energies

Marines. These public-private collaborative projects tackle technological bottlenecks and environmental issues. In all, and over the period 2015-2018, the Government awarded €12 million of R&D funding through this programme.

All along the French coastline, at the regional level, local authorities also support the endeavours of the MRE sector. In addition to grants allocated to R&D federative programmes like the national institute France Energies Marines, or to local initiatives like WEAMEC, they invest in harbour facilities in order to enable the development of offshore wind and tidal industries, thus providing enough space to build plants along new quays, e.g. in Cherbourg, Brest and St-Nazaire.

The two French competitive Sea clusters, Pôle Mer Bretagne-Atlantique and Pôle Mer Méditerranée, have MRE in their roadmaps. Through a labelling process, they foster interest in collaborative projects that can apply for national funding (e.g. the common inter-ministerial fund, FUI), as long as the expected results of those projects can be quickly marketable.

RESEARCH & DEVELOPMENT

Call for projects: Marine Renewable Energies Institute for the Energy Transition 2015-2018

An additional year was awarded to France Energies Marines, in its initial cooperation with the National Research Agency, in order to support collaborative ocean energy R&D projects. Following is a listing of selected projects running in 2018, producing data, software and publications:

DiME - dimensioning and met ocean: modelling and observations of extreme sea states for ocean energy (see picture below);

TIMOTHE, HYD2M and PHYSIC - wave and bottom friction induced turbulence and assessment of sediment transport in the Alderney Race;

ABIOP+ - accounting for biofouling through established protocols of quantification;

MHM-EMR - in service health monitoring of ocean energy moorings to anticipate failures;

STHYF - seafloor cable stability and hydrodynamics in strong tidal currents;

SPECIES - submarine power cable interactions with environment;

COMEET - national panel of experts offering recommendations on environmental and socio-economic issues related to ocean energy;

VALARRAY - optimization software benchmark for tidal & floating offshore wind arrays;

ANODE - quantitative assessment of the metal inputs in the marine environment from galvanic anodes used for ocean energy systems.



DIME project: long-term observatory of extreme waves, using stereoscopy on a lighthouse in the Iroise Sea in order to reduce uncertainties in the calculation of wave-induced stresses.

Call for projects: WEAMEC in the Pays de la Loire Region

Since 2016, this programme has cumulated €5,5 million awarded to projects dedicated to local academic teams in conjunction with industrial stakeholders. Around 10 projects were launched in 2018, covering a broad range of subjects (**ECOSFARM**: tidal control, **DYNA**: advanced geotechnics, **CEAUCOMP**: composite ageing in the marine environment).

Easing access to test sites and tanks: Foresea, Marinet2, TheoRem and Marinerg-i

Ifremer, ECN and Oceanides are involved in the Marinet2 project (<http://www.marinet2.eu/>), offering possibilities for technology developers to test their devices in recognized research facilities, including real sea test conditions. The 2nd call for projects of the Marinet2 European Transnational Access Programme was opened on 15 January 2018 – the selection procedure ended on

18 April 2018: 55 eligible proposals were received. Among these, 34 were granted access to one of the 57 available Research Infrastructures. The 3rd call was opened on 1 November 2018 and closed on 15 December 2018.

Related to this topic, information concerning THEoRem, a National Research Infrastructure related to hydrodynamic testing facilities, which Ifremer and ECN (Ecole Centrale de Nantes) have joined forces to create, can now be found on the research infrastructure website:

www.theorem-infrastructure.org.

Furthermore, Marinerg-I (<http://www.marinerg-i.eu/>), a project devoted to federating in a single European Infrastructure several test sites and tanks, entered the development phase with the elaboration of a shared science plan and a design study. Each country involved agrees on an action plan to deliver necessary commitment letters by April 2019.

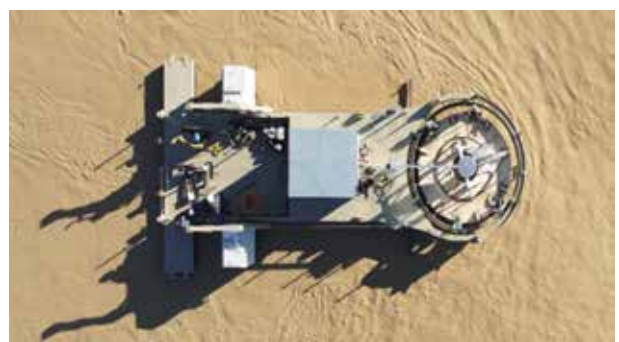
TECHNOLOGY DEMONSTRATION

PROJECTS IN THE WATER

France has now several test centres fully equipped and grid connected where demonstrators are being tested.

At **SEM-REV** on the west coast offshore Le Croisic: Floatgen, the 1st French floating offshore wind turbine has been exporting power to the grid since September 2018. In addition, in the framework of the FORESEA, Eu-Interreg project for the North West Europe area, full scale demonstrators, instrumentation and subsystems for OE are also being tested. Presently being tested are an acoustic monitoring system with SeAc (Nereis Environment) and cable cast iron shells with iBOCS (FMGC).

At **SENEOH**, the tidal test site in the Gironde Estuary in the city of Bordeaux (Grand Opening in March 2018), the 1/4-scale HydroQuest 80 kW marine turbine is the 1st demonstrator to be connected to the grid during an 18-month test. The 2nd user is a 2 vertical axis turbine floating device by DesignPro which required only 3 h of marine operations for its installation.



HydroQuest & DesignPro floating tidal energy converters tested at SENEOH.

At **BREST Saint-Anne**, EOLINK has successfully tested a 1/10-scale floating wind turbine for 4 months, beginning in June 2018.

SABELLA EUSSA project

The SABELLA D10 (10 m diameter) turbine has returned to its pilot site in the Fromveur Passage connected to the Ushant Island grid (Brittany) in October 2018, for another 3-year demonstration programme. Refitting and new monitoring have benefitted from several EU supported projects: ICE for the redundancy of the conversion system and integration of short-term energy storage, MONITOR and REALTIDE for monitoring. In the CF2T project, new gravity based foundations will be designed.



Re-installation of the Sabella D10 turbine in the Fromveur Passage

EEL GEN project

A new round of testing of the 1/6-scale Eel Energy tidal turbine was successfully completed in the Bay of Brest in March 2018. The project partners are Eel Energy, Hutchinson, Baron, Aboard Eng and Ifremer. The tests aimed at membrane and component optimisation and showed a 50% increase in performance.

Video: https://www.youtube.com/watch?v=6Bqnov_sSI8

RELEVANT NATIONAL EVENTS

ICOE 2018

For this 7th edition, ICOE joined forces with Seanergy, the yearly event for marine energies in France, gathering 200 exhibitors, more than 3500 visitors and organized by Bluesign. ICOE 2018 was also mainly supported by the Normandy Region, la Manche Department, the urban community of Le Cotentin and the City of Cherbourg-en-Cotentin. The content of the event was supervised by two committees of international experts led by the Normandy Region through its economic development agency (ADN). Supported by Ocean Energy Systems (OES), the International Conference on Ocean Energy gathers every two years 900 ocean energy academic and industrial experts.

Facts and numbers about the event:

- 3 500 participants, 36 countries
- +220 exhibitors
- 550 B2B meetings
- 140 international speakers
- 65 research posters
- 33 conference sessions



WAVEGEM buoy and project partners during the christening ceremony, 18 December 2018. The project is led by Geps Techno and involves: Chantiers de l'Atlantique, Blue Solution (Bolloré), Centrale Nantes, ICAM, Ifremer and SNEF. The WAVEGEM buoy will be deployed at the Centrale Nantes SEM-REV offshore test site early 2019.

PLANNED DEPLOYMENTS

Launch of the WAVEGEM buoy (IHES project)

The official launch of the WAVEGEM buoy, developed within the framework of the IHES (Integrated Harvesting Energy System) project, took place in Saint-Nazaire on 18 December 2018. One of the objectives of the IHES project, started in 2015 with funding from BPI France, was the design and test of an autonomous multiservice buoy: WAVEGEM.

SABELLA PHARES project

With the aim of demonstrating the availability of renewable energy solutions for an insular community of 2000 inhabitants (Ushant Island), the PHARES project will combine two D12 Sabella turbines, a wind turbine, a PV solar plant and a storage capacity to be operational by 2020.

GERMANY

During 2018 renewable energy in Germany saw record production levels with renewable sources accounting for 38.2 % of energy consumption - generating as much electricity as coal for the first time.

ENERGY POLICY UPDATE

During 2018 renewable energy in Germany saw record production levels with renewable sources accounting for 38.2 % of energy consumption - generating as much electricity as coal for the first time. These figures were achieved on the back of high levels of sunshine during the warmest summer ever recorded and 3 GW of photovoltaic construction - the first resurgence in PV since 2013. Wind generation also increased with an added capacity of only 3.7 GW almost 40% less than in 2017. Offshore wind provided 2.7% to the energy consumption with a production of 19 TWh and a total capacity of 6.3 GW at the end of the year and another 1.4 GW of new capacity expected for 2019 under the expiring previous feed in tariff legislation (EEG 2014).

After years of decline, the tender results for new wind and solar power rose for the first time in 2018. The latest contracts are at 6.26 Cent/kWh for onshore wind and 4.66 Cent/kWh for offshore wind power and 4.69 Cent/kWh for photovoltaics. Not enough approvals for onshore wind energy and a still restrictive surface area for ground-mounted solar plants mean that, contrary to the international trend, the results of the tenders are rising in Germany.

The draft for the so-called "Energy Omnibus Act" that entered the legislative process in November also envisages 'special auctions' to be held. These are designed to speed up the process of expanding the use of renewables and support the attainment of the climate targets. Over the next three years, an additional four gigawatts of capacity both for on-shore wind-powered installations and for solar installations will be auctioned. Under the new legislation, there will also be auctions for innovation. These are designed to test new pricing mechanisms or any other measures making the system more competitive.

Germany's greenhouse gas emissions fell significantly by around 51 Mt or 5.7 % compared to 2017 and are now 31.7 % below the 1990 level at a total of 854 Mt. The reduction is a result of lower primary energy consumption in the industry sector as well as in the heating and transport sectors. A flat economy in the energy-intensive industries and a decline in sales of natural gas, heating oil and diesel contributed to this development. The current gap to achieve the 2020 climate protection target of minus 40 % compared to 1990-levels thus amounts to 103 Mt of CO₂. (source: Agora Energiewende (2019): Die Energiewende im Stromsektor: Stand der Dinge 2018. Rückblick auf die wesentlichen Entwicklungen sowie Ausblick auf 2019. (source: www.agora-energiewende.de)

In summer of 2018 the Federal Ministry for Economic Affairs and Energy launched the Electricity Grid Action Plan to accelerate the expansion process by streamlining planning procedures and improving the way projects are overseen. Existing grids are to be optimised using new technologies and operating strategies. At a grid summit in September, Federal Minister Altmaier and the energy ministers of the Länder, who are responsible for most decisions relating to the expansion of the grid – including planning permissions – agreed on a legislative package to speed up the process of grid expansion.

The Federal Government announced plans to provide € 6.4 billion in funding for energy research up to 2022 within the 7th Energy Research Programme adopted in September 2018 representing an increase of approx. 45% over the period from 2013-2017. The “living labs” or “reality labs” established as part of the energy transition will be made an essential pillar of energy research in Germany. This project type allows for experience to be gained and for regulations to be honed and improved before they are rolled out but in a limited pilot region over a limited period of time. Furthermore, startups are to be given better access to research funding. In contrast to the former editions of the Energy Research Programme, which only provided funding for individual technologies, the focus in the coming years will also be on horizontal issues such as digitisation and sector coupling (Source: Federal Ministry for Economic Affairs and Energy: “Energy transition progress in 2018” from 20.12.2018, <http://www.bmwi-energiewende.de>).

RESEARCH & DEVELOPMENT

In the public sector, around 15 R&D institutes and universities have been involved into developing wave, tidal current and osmotic power mainly in the framework of National and European research projects over the last decade.



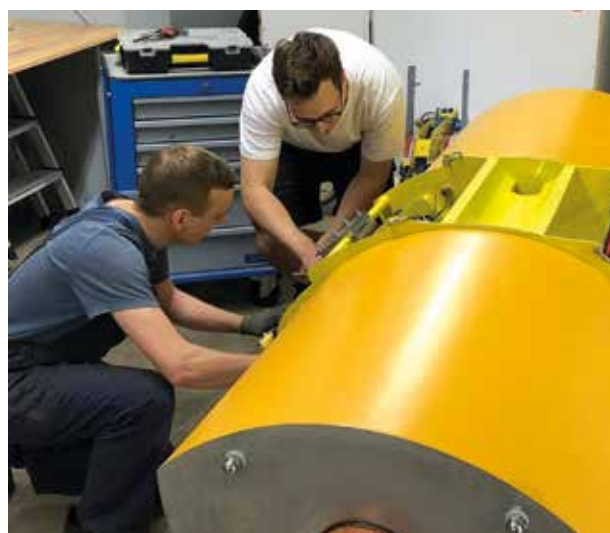
PLAT-I platform being connected to the moorings on September 18th, 2018 (source: SCHOTTEL HYDRO)

In mid 2018 the joint project “TidalPower - Development of a Platform System for Cost Efficient Utilization of Tidal Energy” came to conclusion. The project consortium led by tidal turbine manufacturer **SCHOTTEL HYDRO** delivered the ready-to-build concept of the “TRITON S40”, a semi-submersible platform carrying 40 SCHOTTEL HYDRO tidal turbines rated at 2.5 MW, as well as an improved design of SCHOTTEL HYDRO’s “SIT 250” tidal turbines. Due to a major revision in SCHOTTEL’s business strategy focus of development was directed away from large platforms like the “TRITON” in favour of small platforms like Sustainable Marine Energy’s (SME) “PLAT-I” floating platform, a trimaran equipped with four of SCHOTTEL

HYDRO’s tidal turbines and rated at 280 kW. The platform is currently deployed at the Grand Passage in the Bay of Fundy, Canada, for sea trials.

SCHOTTEL HYDRO, together with part of the TidalPower consortium (Potsdam Model Basin (SVA) and Fraunhofer IEE) and new partners (the Institute of Fluid Mechanics and Hydraulic Machinery (IHS) at the University of Stuttgart and the Center for Wind Power Drives (CWD) at RWTH Aachen University), applied for a successor joint project called “Optimization of a Floating Turbine System for Harnessing Tidal Energy” in 2018, aiming at further improvement of the SIT technology. The project could start in Q1 2019 and would run for 2 years. Furthermore, in 2018 SCHOTTEL HYDRO delivered a power take-off system rated at 500 kW to Swedish tidal kite developer Minesto for utilization in Minesto’s “Deep Green” technology in context with the “Holyhead Deep” project in Wales, UK, which concluded in November (source: SCHOTTEL HYDRO).

The **NEMOS GmbH** together with Uni Duisburg Essen, the Development Centre for Ship Technology and Transport Systems, Schaeffler Technologies AG and LIROS GmbH, continued the development of its wave energy conversion technology in the joint project “Design, Manufacturing, Installation and Commissioning of NEMOS Wave Power Plant Model at 1:1 Scale”. Two of the five sub-projects have concluded yet, delivering the design of an anchorage system and the hydrodynamics, construction and measuring technologies for the WEC. Progress has also been made on the design and construction of a tower serving as WEC foundation, due to be installed in Oostende in 2019. The premanufactured foundation for the top structure was delivered to a shipyard in Poland in December, while first components for the WEC itself have already been ordered. Furthermore, NEMOS successfully tested the first scaled model of their WEC in 2018: The 1:3 scale model was tank tested at the DST Duisburg and later deployed at the Nissum Bredning nearshore test site. (source: www.nemos.org).



NEMOS WEC 1:3 scale model (source: NEMOS)

Wave power developer **SINN Power GmbH** continued the work on the project “Testing of a Modular Concept for the Generation of Grid Conform Electricity from Irregular Ocean Waves in a Generator Array” which was started in 2017. The project runs until July 2019 and is supposed to deliver four additional WEC modules to the existing test site at the port of Heraklion, Greece. Two second generation WECs were successfully put into operation in July.

Furthermore, a floating WEC grid of 21 modules is planned to be installed at an organic shrimp farm on the island of São Vicente, Cape Verde. In March it was agreed between SINN Power and customer Fazenda de Camarão to launch the project shortly with a detailed feasibility study and measurement campaign. In August, SINN Power announced the launch of a paid feasibility study in West African Guinea. On behalf of customer Guinea Gold PLC, SINN Power was commissioned to conduct a 9-month

feasibility study in the Guinean capital of Conakry to assess the potential of wave energy and other renewable sources of energy. In this context SINN Power installed autonomous measuring systems for renewable energies in Conakry in November, opening the second phase of the project. The aim of the feasibility study is to make a site-specific recommendation for a renewable hybrid system including wave energy (source: www.sinnpower.com).

Other German suppliers, such as Bosch Rexroth, Schaeffler, Contitech, Thyssen Krupp, Hunger Hydraulik and Hydac deliver components and parts for a number of ocean energy devices – for wave as well as tidal turbine technologies, mainly in Europe. Certification companies such as the DNV GL-Group and consultants are contributing to the technology and project development in the sector. This international collaboration demonstrates the technology export opportunities, which exist in ocean energy for the German industry.



Second generation SINN Power WECs at the port of Heraklion, Greece

INDIA

The project on first ever Ocean Thermal Energy Conversion (OTEC) powered desalination plant in Kavaratti, Lakshadweep Islands, was approved by the Government.

OVERVIEW

The project on first ever Ocean Thermal Energy Conversion (OTEC) powered desalination plant in Kavaratti, Lakshadweep Islands, was approved by the Government. As part of the product development for usage in ports, a wave powered navigational buoy was installed successfully with additional oceanographic sensors off Kamarajar Port, Chennai.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The National Institute of Ocean Technology (NIOT), an autonomous institute under the Ministry of Earth Sciences (MoES), has been entrusted to develop technologies pertaining to ocean energy. NIOT also advises the Ministry of New and Renewable Energy (MNRE) (which is primarily responsible for tariff fixation and policy formulation for renewables), on ocean renewable energies as and when required.

PUBLIC FUNDING PROGRAMMES

The Ministry of Earth Sciences, under the Government of India, supports the programme on Ocean Energy and Desalination at NIOT.

RESEARCH & DEVELOPMENT

NIOT has been working on Oscillating Water Column (OWC) principle based wave energy devices for some years. Continuing the ongoing development on the wave powered navigational buoy, NIOT team has successfully demonstrated an all weather floating wave powered navigational buoy using wave energy for powering a beacon lamp on the top of the buoy and oceanographic sensors. The buoy has been continuously



Unidirectional turbine / Bidirectional turbine



Open Cycle OTEC turbine for laboratory studies

operating for several months near the navigational channel of Kamarajar Port, in Chennai, India. Measured oceanographic parameters have been hourly transmitted to port authorities through GSM communication.

Both unidirectional and bidirectional impulse turbine for wave energy devices have been tested in open sea trials of wave powered navigational buoy for their performance evaluation. The performance of the bidirectional turbine developed in collaboration with Indian Institute of Technology, Madras (IIT-M), is being compared with that of the unidirectional turbine.

Experimental studies on various components of Ocean Thermal Energy Conversion (OTEC) and Low Temperature Thermal Desalination (LTTD) have continued in the recently established laboratory at NIOT, Chennai. The plant can be operated for the Open Cycle OTEC, Closed Cycle OTEC as well as Desalination in various seawater temperature scenarios. The laboratory is equipped with a comprehensive supervisory control and data acquisition (SCADA) system.

The design and several activities for the project on establishment of the OTEC powered desalination plant in Kavaratti, Lakshadweep Islands, have been initiated.

TECHNOLOGY DEMONSTRATION

PROJECTS IN THE WATER

A wave powered navigational buoy has been tested several times before hand over to the Kamarajar port in Chennai. It has been installed in the navigational channel of the port.

PLANNED DEPLOYMENTS

As part of the transfer of technology to Industry, NIOT is building two more wave powered navigational buoys. These are planned to be deployed at two different ports in India. NIOT also has a design ready for a hydrokinetic turbine of installed capacity 5 kW for the Andaman and Nicobar Islands.

RELEVANT NATIONAL EVENTS

A conference of Energy & Water is being organized on 7-9 March 2019 at NIOT campus.

The Foundation Stone for OTEC powered desalination plant was laid in Kavaratti by Honourable Minister of Science and Technology, Earth Sciences and Environment & Forests, Government of India.



IRELAND

Ireland is actively committed to harnessing its abundant wave, tidal and offshore wind energy resources while developing an indigenous ocean energy industry in the process. 2018 saw the completion of the review of the Offshore Renewable Energy Development Plan.

OVERVIEW

Ireland is actively committed to harnessing its abundant wave, tidal and offshore wind energy resources while developing an indigenous ocean energy industry in the process. 2018 saw the completion of the review of the Offshore Renewable Energy Development Plan. The review confirmed that all relevant agencies and Government departments within Ireland remain committed to support this burgeoning sector and offering one single gateway for information and access to the ocean energy industry in Ireland.

Development of Irish technologies such as OE Buoy and Gkinetic were also greatly progressed in 2018. OE Buoy has completed build of its 500 kW machine in Vigor ship yards in Oregon USA. The buoy will be transported for testing in Hawaii in Q1 2019. Gkinetic tested 25KW prototype in Bordeaux in France. Disappointingly, 2018 was also the year that Naval Energies ceased production of the Irish based OpenHydro tidal technology, despite successfully deploying a 2MW machine in Canada in July 2018 and securing options to deploy in France. Regardless the industry is progressing and knowledge gained in the development and operation of this technology has not been lost, given that many have chosen to reinvest their knowledge and expertise into other companies within the sector.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

In 2014 the Department of Communications, Energy and Natural Resources (DCENR) published the Offshore Renewable Energy Development Plan (OREDPP) (<http://www.dcenr.gov.ie/energy/en-ie/Renewable-Energy/Pages/OREDPP-Landing-Page.aspx>). The OREDPP highlights the potential opportunities for the country relation to marine energy at low, medium and high levels of development, as derived from the findings of the Strategic Environmental Assessment of the Plan carried out prior to publication. The OREDPP, as a policy document, sets out the key principles, specific actions and enablers needed to deliver upon Ireland's significant potential in this area. Accordingly, the OREDPP is seen as providing a framework for the development of this sector. The over-arching vision of the Plan is "Our offshore renewable energy resource contributing to our economic development and sustainable growth, generating jobs for our citizens, supported by coherent policy, planning and regulation, and managed in an integrated manner" (DCENR, 2014). The Plan is divided into two parts. The first part deals with the opportunities, policy context and next steps, including 10 key enabling actions for the development of the sector. The second part focuses on the Strategic Environmental and Appropriate Assessment of the Plan.

The implementation of the OREDP is being led by the Department of Communication Climate Action and Environment (DCCAE) who have put in place the Offshore Renewable Energy Steering Group (ORESG) in order to ensure successful implementation. The Steering Group consists of the main Government departments and agencies with roles and responsibilities that relate to energy and the marine environment, developers and broader interest and user groups when necessary.

The work of the ORESG, and hence the implementation of the OREDP, is organised according to three work-streams: Environment, Infrastructure and Job Creation. The Job Creation working group has responsibility across several actions, including identifying additional exchequer support requirements, supply chain development and communicating the message that 'Ireland is Open for Business'. Under the Environment work-stream the Group ensures the needs of the marine energy industry are reflected in the on-going reform of the foreshore and marine consenting process. The actions deriving from the SEA and AA of the OREDP are also taken forward under this work-stream to ensure that future marine energy development takes place in an environmentally sustainable manner. The Infrastructure working group concentrates on supporting and delivering objectives of other policies such as the National Ports Policy and Grid 25 so as to expedite integrated infrastructure development which will facilitate the offshore renewable energy sector.

This plan was reviewed in 2017 by relevant stakeholders at government and industry level to ascertain progress on actions; to ensure continued focus on appropriate priority areas and to realign the plan with any changes in political or technical landscapes. The review of the OREDP was subject to a full public consultation in November/December 2017. The final report of the review was published in May 2018. The review contains 26 recommendation actions which can be reviewed in the link below. This review does not make any changes to the OREDP; rather the review aims to chart progress on the plan, identify challenges that have emerged and identify areas that need to be prioritised or require attention.

MARKET INCENTIVES

In September 2017 the department of Communications Climate Action and Environment issued a the 'Public Consultation on the Design of a new Renewable Electricity Support Scheme in Ireland'. This public consultation focused on the design options of the proposed new RESS for Ireland. This was the second stage in this process to review and design Irelands Renewable Energy Support Scheme (the initial consultation had been issued in July 2015).

While the primary objective of the new RESS is to incentivise the introduction of sufficient renewable generation to deliver national and EU wide renewable energy and decarbonisation targets, there are other

energy policy objectives. The objectives include: the broadening and diversifying of the renewable technology mix, enhancing security of energy supply, promoting economic development, and supporting community and citizen participation in the transition to a low carbon economy. These objectives must be met, while simultaneously delivering value for money for the consumer. Providing pathways for increased community participation is also considered be a cornerstone of the new scheme, delivering on Energy White Paper commitments.

The proposed new RESS has been designed with the primary policy objective of delivering sufficient renewable electricity to meet Ireland's contribution to the EU wide renewable energy targets, out to 2030. The proposed design also meets Ireland's three energy pillars of Competitiveness, Security of Supply and Sustainability, while simultaneously addressing other stated government ambitions. The Floating Feed In Premium (FIP) performed best against the assessment criteria and was selected as the primary financial support mechanism for the new RESS. This support will be allocated through auctions, with potential exceptions for small-scale generation or emerging technologies.

A separate Community Category is also included within the RESS to support community-led projects. Several proposals regarding the features of a community scheme within the new RESS consultation were suggested. These proposals included: projects supported under the RESS must offer the community an opportunity to invest, a floating feed-in-premium (FIP) should be made available for smaller community projects (<6MW wind, <1MW other technologies), and development grants should be made available to suitable community-led projects. The report also explored several means of enabling communities to make their investments, including tax incentives, green bonds, facilitating crowd funding and offering investment soft loans. No recommendation is made regarding supporting these options, but further analysis of these measures is proposed to understand their suitability. It is also proposed that pathways for micro-generation be developed outside of, but in conjunction with, the main RESS.

The DCCAE are currently in the process of seeking state aid approval for the scheme. It is anticipated that the first auction call will open in 2019.

PUBLIC FUNDING PROGRAMS

SEAI Prototype Development Fund

SEAI's Prototype Development Fund aims to accelerate and enhance support for the research, development, testing and deployment of wave and tidal energy devices. The emphasis is on industry-led projects, and covers a broad scope, including the following indicative types of activities:

- Projects to develop and test wave and tidal energy capture devices, systems and sites.

- Independent monitoring of projects/technologies.
- Industry-led R&D aimed at the integration of ocean energy into the electricity market and the national electricity grid (and network).
- Data monitoring, forecasting, communications and control of ocean energy systems.

The programme launched in 2009 and to date has supported over 110 projects with +€17m grant funding. Many projects supported through the programme have utilised Ireland's suite of test facilities, particularly development of small-scale physical models in the wave basins at the National Ocean Test Facility at University College Cork and sea trials in Galway Bay.

Pre-Commercial Technology Fund

To meet the changing requirements of the ocean energy sector, and particularly ocean energy technology developers, SEAI is investigating funding mechanisms to help accelerate the commercialisation of wave and tidal energy devices and components. In 2016 the Marine Renewables Industry Association (MRIA) published its report 'Funding the Development of the Ocean Energy Industry in Ireland', with the support of SEAI. This report recommends the establishment of a 'Pre-Commercial Technology Fund (PCTF) to close the 'funding gap' for device and sub-system developers at TRL3+ and to complement the current Prototype Development Fund'.

SEAI commissioned Black & Veatch and Carbon Trust to carry out two studies to explore options for expanding SEAI's schemes as per MRIA proposals. These studies considered the Development of Funding and Governance Options for Irish Ocean Energy Programme and Ocean Energy Technology challenges. Following the completion of the studies, SEAI held a workshop with industry to present the findings of them and to gain feedback from industry on a possible pilot programme. SEAI are continuing to explore ways of establishing a pre-commercial fund, including the option to collaborate on a H2020 project which will leverage EU funds for such a programme.

OCEANERA-NET

The ERA-NET scheme was an innovative component of the European Union's Framework Programme, which supported co-operation of national/regional research funding programmes to strengthen the European Research Area (ERA). OCEANERA-NET (<http://www.oceaneranet.eu>), aimed to coordinate and support research, innovation and knowledge exchange in the Ocean Energy sector amongst European countries and regions, by launching transnational competitive joint calls for funding collaborative RTDI projects. SEAI participated in the OCEANERA-NET project, along with 16 funding Agencies from 9 European countries.

The OCEANERA-NET programme, which ran from December 2013, closed in February 2018, following two successful joint calls for collaborative research and innovation projects. Six projects with nine Irish partners were approved in the two OCEANERA-NET joint calls.

SEAI are continuing to explore ways of establishing a pre-commercial fund, including the option to collaborate on a H2020 project which will leverage EU funds for such a programme.

There are currently two active OCEANERA-NET projects with Irish partners.

Ocean Energy ERA-NET Cofund

The Ocean Energy ERA-NET Cofund (OCEANERA-NET COFUND) project is a five-year action that secured support through the European Union's Horizon 2020 Programme for Research and Innovation in 2016. This new programme will build on the work of OCEANERA-NET and with an increased budget and financial support from the EU Commission, the COFUND programme focuses on collaborative projects that demonstrate and validate innovative technologies for ocean energy.

OCEANERA-NET COFUND aims to support transnational, collaborative research and development projects in ocean energy through joint calls and carry out other joint activities which will enhance the coordination of public research and innovation programmes and improve the exploitation of results of the projects funded. The first joint call was launched in 2017 and was open to applicants from three European countries (Ireland, Spain, Sweden) and four regions (Brittany, Pays de la Loire, the Basque Country, and Scotland). Three projects, with four Irish partners, were awarded grants in the COFUND joint call.

RESEARCH & DEVELOPMENT

Marine Renewable Energy Ireland (MaREI)

MaREI is a research, development and innovation centre, supported by Science Foundation Ireland, that focuses on the advancement of energy and marine research, innovation, and commercialisation to facilitate Ireland's leadership in confronting urgent global challenges, specifically the energy transition, climate action, and blue growth. By the end of 2018, MaREI had over 200 researchers in place working on a variety of fundamental and applied research projects across its six academic partner institutions. These included targeted projects

with over 50 industry partners, comprising a range of SMEs and MNCs across the energy and marine spaces, and involved engagement with stakeholders from across government, academia, and society to deliver the underlying policy context, societal engagement, and capacity building necessary to support Ireland's leadership in confronting the aforementioned global challenges.

MaREI's research capabilities draw upon the excellent track record of well-established marine and renewable energy-based research groups across each of its academic partners, covering a wide range of cross-cutting topics such as device design and testing, novel materials, offshore operations, coastal and marine management, marine robotics, observation and monitoring, energy storage, aquaculture and green gas. The research team comprises internationally recognised experts in these fields from University College Cork, National University of Ireland, Galway, University of Limerick, Maynooth University, University College Dublin and Cork Institute of Technology, who have complementary research backgrounds key to providing the underpinning research necessary for Ireland to achieve commercially successful marine and renewable energy industries.

Lir National Ocean Test Facility

The Lir National Ocean Test Facility (NOTF) is a world-class centre for renewable energy and marine research, located in the UCC Beaufort Building in Ringaskiddy, Co. Cork. Lir is a custom designed test facility which features upgraded and expanded tanks and equipment for the testing of small-scale ocean energy renewable devices. Testing infrastructure includes:

- A Deep Ocean Wave Basin (circa 1:15 scale testing).
- The Open Ocean Emulator, an ocean wave basin with a sophisticated 2-sided paddle system and a two sided absorption system (circa 1:50 scale testing).
- A wave and current flume with coastal/tidal testing capabilities (circa 1:50 scale testing) and a wave demonstration flume.
- Mechanical and electrical workshops.
- Electrical testing infrastructure, including a smart-grid and a series of linear and rotary rigs used to test power take-off and energy storage.

Lir is an essential part of Ireland's ocean energy research and testing infrastructure and provides a significant launch pad for both national and international marine renewable energy developers.

All tank and infrastructure commissioning has been completed on site and the Lir National Ocean Test Facility was officially opened in January 2019.

EU Projects

Ocean Energy projects that Irish partners are participating in through European-funded programmes include:

The H2020 INFRARIA 2016-2017 **MaRINET2** project

will provide and co-ordinate free access to ocean energy developers to test infrastructure throughout Europe. MaRINET2 has built upon the previously successful MaRINET programme. UCC are project co-ordinators. Facilities at NUI Galway and the University of Limerick are also included, as well as the Galway Bay Marine and Renewable Energy Test Site.

The H2020 INFRADEV 2016-2017 **Marinerg-i** project, led by UCC, aims to unite Europe's leading renewable energy research organisations to become the leading international distributed infrastructure. Its integrated nature and co-ordinated approach will accelerate the research development and deployment of offshore wind, wave, tidal and combined energy technologies and help maintain Europe as a global leader in this sector.

The H2020 **TAOIDE** proposal is to develop a fully-integrated generator to grid energy delivery system with high reliability and availability, suitable for use in multiple architectures of marine renewable energy systems. This work will provide the basis for development of a power production system certified for use in marine renewable energy applications – a system designed for the specific environments and regulations of the European Union market, utilising skills, expertise and capabilities of European partners. The Irish partners in these projects are ORPC Ireland, UCC, and Letterkenny Institute of Technology.

The H2020 **OPERA** (Open Sea Operating Experience to Reduce Wave Energy Cost): The primary objective of OPERA is to gather open-sea operating experience to reduce the cost of wave energy. A key challenge to realising the potential of Europe's wave energy resource relates to data access; the wave energy R&D community does not always have access to open-sea operating test data. OPERA will remove this roadblock by collecting and sharing two years of open-sea operating data of a floating oscillating water column wave energy converter. UCC/MaREI are a contributing partner

The H2020 **FloTEC** Project (Floating Tidal Energy Commercialisation): The FloTEC project will demonstrate the potential for floating tidal stream turbines to provide low-cost, high-value energy to the European grid mix. The project will entail the construction of a turbine device that will be deployed alongside an existing floating tidal array which will serve as a demonstration platform for commercially viable tidal stream energy. Irish partners include UCC/MaREI and Eirecomposites.

INTERREG NWE **FORESEA** project (Funding Ocean Renewable Energy through Strategic European Action). This project brings ocean energy technologies to market by providing access to North-West Europe's world-leading network of open sea test centres. Through the project, the performance of innovative ocean renewable energy technologies will be demonstrated in real sea conditions, helping to leverage the investment needed to take these new products to market. Irish Partners are Smartbay Ireland and access to the Galway Bay test site can be achieved through this mechanism.

INTERREG Northern Ireland, Ireland and Scotland **BRYDEN PHD Programme**. This programme offers fully funded PhD Studentships in Marine renewable energy and Bio-energy in the following institutions - Queen's University Belfast, University of the Highlands and Islands, Letterkenny Institute of Technology, Ulster University, Agri-Food & Biosciences Institute, Donegal County Council and Dumfries and Galloway Council. Using a Doctoral Training Centre model, the BRYDEN CENTRE project will recruit 34 PhD students and 6 PDRAs; each of whom will work with industry to produce industrially relevant research with the potential for commercial exploitation and resulting economic growth within the region. Final output will be 68 peer reviewed journal and conference publications with cross border authorship. Letterkenny IT are the Irish Partners in this project.

INTERREG NWE **OPIN** project (Ocean Power Innovation Network) is a 3 year project running from October 2018 to December 2022. OPIN will design, test and deliver an innovation model to build cross-sectoral collaboration, to accelerate growth of the Ocean Energy sector and its supply chains. OPIN will build an environment where SMEs can collaborate transnationally, and across sectors, and build wider supply chains for the Ocean Energy sector. OPIN activities include the growth of a transnational cross sector network, challenge calls for cross-sectoral collaborative innovation projects, and tailored support to SMEs. Irish partners include SEAI, as lead partner, with MRIA, ESB and Enterprise Ireland as associate partners.

INTERREG NWE **AFLOWT** (Accelerating market uptake of Floating Offshore Wind Technology) project will run from January 2019 to December 2024. The project aims to build a full-scale floating wind device to deploy and test in the Atlantic Marine Energy Test Site (AMETS) in Belmullet. This will demonstrate the investability of floating wind technology and promote its uptake in north west Europe and globally.

H2020 **OceanSET** (Support to the Realisation of the Ocean Energy Implementation Plan of the SET-Plan) project run from February 2019 to December 2021. The project was developed to support the Implementation of the European Strategic Energy Technology Plan (SET Plan) for Ocean Energy. The Implementation Plan focuses on the key challenges for wave and tidal energy technologies. Its ambition is to outline a structured approach that will enable wave and tidal technologies to follow a credible development path, with the ultimate destination of a commercially viable wave and tidal industry. SEAI the lead partner in this project and is the only Irish partner.

INTERREG NWE **MEA** project (Marine Energy Alliance) is a 4-year project running from May 2018 to May 2022. 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. Irish Partners include Exceedence Ltd and MaREI (Marine and Renewable Energy Ireland).

TECHNOLOGY DEMONSTRATION

PROJECTS IN THE WATER

Ireland's Galway Bay Test Site was awarded a new 35 year lease this year and the award of the lease allowed for the test site to be recommissioned in July 2018. Since recommissioning, the test site has deployed a number of smaller projects, and the pipeline for 2019 looks promising in particular there has been much interest in the floating wind test berth.

Some of the smaller projects deployed on site in the latter half of 2018 included a glider with acoustic sensors, the glider was deployed and piloted at the test site where it collected acoustic data 24 hours a day over a period of 7 days. The project will facilitate an acoustic landscaping of the area and a comparison between the glider hydrophone data against the fixed PAM system on the subsea observatory.

Anteia: Funded by an EU project Jerico-Next, a Spanish company called Zunibal deployed their wave monitoring equipment at the test site. Zunibal are testing a directional wave buoy called Anteia. This project will validate this technology against the permanently deployed Waverider buoy at the test site. Two other projects funded under Jerico-Next were also deployed on the observatory relating to microplastics and video analysis of benthic communities.

eForcis: Also deployed on site in 2018 was a small-scale energy harvesting device called eForcis. The energy harvesting device is housed in a water tight box which sits on top of a Marine Institute buoy and uses the motion of the buoy and simple electromagnetic principles to harvest energy. The energy generated in this novel device can be used as an alternative power source to address electricity supply shortages in off-grid marine devices operating in harsh marine conditions. The Spanish company are funded by the EU Ocean-EraNet programme and the SME. instrument to trial and validate the eForcis design in SmartBay and will perform a second trial in 2019 of beForcis, which is an improved eForcis device.



Eforcis testing in Galway Bay

In 2017, DesignPro were funded €1.9 million from EU's Horizon 2020 SME Instrument Programme for a €2.7 million project to develop and commercialise small-scale turbines. The 27-month project kicked-off in July 2017 and the company have achieved a number of milestone deliverables including the deployment of a 25 kW turbine at the SEENEHO test site in Bordeaux, France where it is undergoing rigorous performance and environmental testing.



DesignPro 25 turbine at the SEENEHO test site

PLANNED DEPLOYMENTS

New Wave Technology trading as Ocean Energy plan to test a half scale model in US Navy WETS facility in Hawaii in Q1 2019. The project is co-funded by both SEAI and DOE in the US. The project has been in place since 2016 and up to now has focussed on transport and access to the site. It is stage/phase 4 of the Development & Evaluation Protocol for Ocean Energy technology, the prior stages having been completed with financial assistance from the Marine Institute, Enterprise Ireland, EU funding and SEAI. The prior stage included several deployments at the Galway Bay Quarter Scale test site – during which the device accumulated over 24,000 hours of open water testing.



OE Buoy Build December 2018

RELEVANT NATIONAL EVENTS

Ocean Energy Europe Conference

The annual Ocean Energy Europe Conference and Exhibition is one of the most important events on Europe's ocean energy calendar. This year's conference will take place in Dublin in October 2019. The conference will provide opportunities to network and obtain access to decision makers, thought leaders, investors and entrepreneurs in the sector.

Ocean Power Innovation Network

The Ocean Power Innovation Network (OPIN) is an EU project, funded through Interreg NWE, led by Irish partner SEAI. The previously established OPIN initiative sought funding to expand the number of regions in which it operated. To date OPIN has facilitated 4 workshops, held in Dublin, Edinburgh, Belfast and Aberdeen, which highlighted opportunities for learning and technology transfer from other sectors such as offshore oil and gas and encouraged collaboration. The project will achieve its objectives through a programme of symposiums, workshops, and masterclasses to be held over the 3 years of its lifetime. Ireland will directly organise at least two cross-sectoral workshops and will hold the annual OPIN Symposium in Ireland in 2019. SMEs in the sector will also have access to workshops and masterclasses organised in all of the project partner regions over 2019-2021.

The Ocean Energy Ireland Portal

The portal, designed by SEAI and the Marine Institute with input from numerous other groups, acts as a 'one stop shop' to guide developers through the supports available in Ireland for the marine renewable energy sector. All information is aligned under six axes of activity that provide access to marine data, maps, tools, and funding support information.

www.oceanenergyireland.com

2018 saw numerous new or upgraded features. The Marine Renewable Energy Atlas, an interactive GIS map of Ireland and its territorial waters, was updated to include the most relevant, high quality downloadable data available. Including test site infrastructure, INFOMAR data, socio-economic data, monthly model means from East Atlantic SWAN numerical model and North Atlantic ROMS numerical model, research facilities locations, ports locations. The media section of the website was also redesigned in 2018 to provide regular updates on Ireland's key activities and achievements in the ocean energy sector.

ITALY

At the end of 2018, Italy presented to the EU Commission the draft of the National integrated Energy and Climate Plan (NECP), setting challenging energy and environmental targets for 2030.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

At the end of 2018, Italy presented to the EU Commission the draft of the National integrated Energy and Climate Plan (NECP), setting challenging energy and environmental targets for 2030. NECP was presented by the Ministry of Economic Development, the Ministry of Environment and the Ministry of Transport and Infrastructures, but it was prepared with the collaboration of various high level technical and research bodies.

Renewables are expected to grow remarkably, getting to very high levels of penetration in the electricity sector, above 50%. A key role will be played by mature technologies such as photovoltaic and wind plants, which will be promoted through competitive mechanisms and regulatory actions. However, innovative and promising technologies, including marine, are also encouraged to give a contribution to 2030 targets. In that context, the NECP draft announced that ad-hoc measurements will be put in force for such innovative technologies.

The cluster “Blue Italian Growth” (BIG), led by the Italian National Research Council (*Consiglio Nazionale delle Ricerche – CNR*), has continued its progress towards the establishment of an open structure for the aggregation of all the national actors involved in all the different sectors of the Blue Economy, including Marine Renewables. Sectoral Action Plans have been developed and are currently being finalized.

MARKET INCENTIVES

While waiting for the measurements foreseen by the new Italian NECP, D.M. 23/06/2016 was the latest operative support scheme, currently in force. The Decree updated the support scheme previously regulated by DM 6, July 2012. The latter reviewed the preceding framework based on Feed-in Tariffs and Green Certificates, for renewable plants (other than Photovoltaic) in operation starting from 1 January 2013.

The most recent DM identifies four different ways of access to incentives: direct access, bid auctions (Dutch Auctions), registries for new power plants, for fully reconstructed power plants, for reactivated, empowered and hybrid power plants and registries for rebuilding intervention. The Decree defines the criteria to access the registries and the Dutch Auctions and establishes specific limits for the annual capacity eligible to incentives. These limits are set up differently for each kind of renewable energy source and for all the different ways of access to incentives (registries or bid auctions).

In general, the Decree grants a fixed tariff plus, in some cases, a specific premium, to provide incentives to net electricity fed into the grid. The fixed tariff is different according to each source, technology, and capacity range considered. Power plants with a capacity > 500 kW can only receive the incentive (fixed tariff minus electricity hourly zonal price, plus premiums if foreseen). Power plants with a capacity ≤ 500 kW can alternatively receive a Feed-in Tariff composed by the fixed tariff plus, in some cases, a specific premium.

In the Dutch Auctions, the maximum requested value of the tariff cannot be higher than a 2% discount of the reference value and the minimum value cannot be lower than a 40% discount of the reference value. The incentives last for the average conventional plant life of each typology of power plant. All the support schemes are managed by the Italian Energy Service Operator (Gestore Servizi Energetici - GSE), the body in charge of managing all the incentives to renewable energy.

New, fully reconstructed, reactivated or empowered wave and tidal energy power plants can access directly to incentives if their capacity is not greater than 60 kW, otherwise they must apply for access to registries. The direct access to incentive was in force up to the end of 2017, but no plant has benefited from this incentive.

Typology of power plant	Capacity	
	≥ 1 kW and ≤ 60 kW	> 60 kW and ≤ 5 MW
Wave and tidal power plants	Direct Access ¹	Registry

¹ If the power plant is built by the Public Administration, the maximum capacity eligible to direct access is doubled (120 kW).

From 2013 to 2016, the total annual capacity (MW) eligible for access to registries, and therefore for the granting of incentives, amounted to 6 MW. To this day, only one project, with capacity of 99 kW, located in Tuscany, retains the right to access incentives, but it has not been realized yet. The Decree does not provide for Dutch Auctions in the case of wave and tidal energy power plants.

For new wave and tidal energy power plants, DM 23/6/2016 confirmed the previous tariff, as follows:

Source	Typology	Capacity (kW)	Conventional Plant's Life (years)	Fixed Tariff €/MWh
Oceanic (tides and waves)		1 < P ≤ 5000	15	300

The Directive 2014/89/EU on Marine Spatial Planning is also relevant for the specific Blue Energy sector, as it establishes a framework for the implementation of maritime spatial planning and integrated coastal management by Member States, aimed at promoting the sustainable growth of maritime economies, the sustainable development of marine areas and the sustainable use of marine resources. The Directive has been recently transposed into the Italian legislation via the D. Lgs 201/2016.

PUBLIC FUNDING PROGRAMMES

Italy relies on a public research programme aimed at maintaining and improving the national energy system, including the still limited marine energy sector. Such programme, named Ricerca di Sistema (System Research), pursues as its main objective the promotion, organization and management, of basic and industrial research, and of the related technological development, finally ensuring maximum fruition of results to all citizens and end users.

The Committee of Research Experts for the Electricity Sector (Comitato di Esperti di Ricerca per il Settore Elettrico - CERSE) plays a strategic role in orienting R&D activities towards the innovation of the electrical system, through funding under the EU principles that regulate State aid for Research and Development and Innovation. (Communication from the Commission 2014/C 198/01). The CERSE is composed of five members, appointed by the Minister of Economic Development, and is responsible for regulating public funding for research projects of general interest in the electricity sector.

The Ministry of Education, University and Research (Ministero dell'Istruzione, dell'Università e della Ricerca – MIUR) has launched two calls for proposals to grant funding for strategic research activities, including the Blue Energy sector. In particular, two Directorial Decrees have recently been issued:

- Decree N. 1610/3 August 2016, for the recognition and the subsequent development of four national technology clusters aimed at coordinating public and private research initiatives, as well as national

governance and territorial policies, in accordance with the representatives of major national enterprises. One of the clusters is dedicated to the Economy of the Sea, with specific reference to Blue Energy as one of the fields of interest. Among these, potentially connected sectors are also explicitly mentioned, such as shipbuilding, environmental monitoring and protection, aquaculture and blue biotechnologies. Applicants, constituted as competing consortiums, were requested to formally authorise a representative selected among their members, in the form of an individual authorisation, and to further substantiate their initiative by presenting an Action Plan and two original industrial research projects. Applications have been assessed according to the quality of the proposed Action Plan and projects, and the evaluation results published in the Directorial Decree N.1853/26-07-2017. The cluster "Blue Italian Growth" (BIG), led by the Italian National Research Council (Consiglio Nazionale delle Ricerche – CNR), has been granted access to financial support, while the Blue Energy project TEOREMA (Technological Solutions For Multi-Objective Off-Shore Energy Platforms), ranked first in its category, is to enter into negotiation.

- Decree N. 1735/13 July 2017, a call for proposals targeted at projects focused on industrial research and experimental development in the 12 areas of specialization individuated by the Italian National Research Programme (Programma Nazionale per la Ricerca – PNR) 2015-2020. The strategic areas include Blue Growth, and Blue Energy is explicitly mentioned as a relevant sector.

Such initiatives are expected to contribute to the rationalization of the Italian activities in the Blue Energy field, and to systematically support the so far isolated efforts of the national actors, amplifying their collective impact by connecting different economic sectors, as well as relevant stakeholders from the business community, the government and civil society, thus also helping to create a systematic framework of rules and incentives. As a matter of fact, the Italian research community has so far resorted to a variety of independent public funding sources, either national or international, which, albeit significant in terms of prestige, do not guarantee the constant, coherent and predictable support required to fully exploit the Italian potential and to consolidate Italy's position in the international market.

RESEARCH & DEVELOPMENT

All the actors from the private and academic sectors that were already included in the 2017 Report are actively involved in R&D activities to further improve their devices, increase their technology readiness level (TRL) and lower their levelized cost of electricity (LCoE). Here we only present cases of substantial upgrade and relatively high TRL.

RESEARCH INFRASTRUCTURES

Design and installation of the SeaPower Natural Laboratory in Vialla San Giovanni (RC)

The University of Naples "Federico II" has a long-standing experience in the design and testing of tidal energy converters. The university spin-off SeaPower scrl, a non-profit private consortium that already patented new marine energy converters, is now bound to implant a natural laboratory offshore Villa San Giovanni (RC), for the development, optimization and monitoring of innovative devices for the exploitation of tidal currents. Its location in the Strait of Messina is ideal for the significant intensity of local currents and the extremely favourable climatic conditions offered throughout the year, two requirements that are rarely simultaneously met in the Mediterranean Sea. The authorization process for the construction of the laboratory is in progress: the Environmental Impact Authorization has already been granted and the detailed project for the onshore infrastructures has been submitted to the Ufficio del Genio Civile OO.MM. (Civil Engineering Department, Coastal Operations). The official permission for building is expected to be granted soon by the Municipality of Villa San Giovanni, and to be immediately followed by the necessary Public Maritime Domain concession.

Due to the peculiar hydraulic characteristics of its location (Punta Pezzo), the SeaPower laboratory will represent a unique facility in the Mediterranean, offering the opportunity to test both full scale and reduced scale prototypes in a fully monitored natural environment. The laboratory will consist of five areas, permanently designated for the monitoring and testing of prototypal turbines, of a test area on the existing artificial pier and of an onshore laboratory to host the related infrastructure assets. An additional artificial breakwater will be built in the proximity of the marine test areas for logistic support to operations at sea. Submerged cables will connect the converters at sea and the monitoring equipment to a submarine hub, from which a single cable will carry both the electric current produced and the acquired data to the onshore lab.

INNOVATIVE CONVERTERS

PIVOT Wave Converter (TRL 5)

The PIVOT system is a Wave Energy Converter (WEC) that consists in a hinged floating body oscillating under the effect of wave motion and an electric generator, connected via high-tech components. It has been developed from the GEL prototype by Seapower scrl in collaboration with the University of Naples "Federico II".

The shape and inertial characteristics of the floating body have been specifically designed, as well as the structure that fastens it to the rotating axis connected to Power Take-Off (PTO) system.

The conversion of mechanical energy can be achieved through a variety of technical solutions. The PTO currently consists of an electric generator coupled to a recirculating-ball screw that was designed in collaboration with the manufacturer, Umbra Group Spa. The PTO is connected both to the oscillating body (via a piston and a hinge) and to the fixed structure. Wave motion forces the system to oscillate and induces the consequent rotation of its hinged axis, which results in the linear oscillation of the piston that is finally transmitted to the generator via the recirculating-ball screw. Both reduced scale and full scale prototypes of the system have been tank tested, reaching TRL 5. Testing in real sea conditions was scheduled for December 2018, when a full scale PIVOT prototype using the described system configuration was to be anchored onto a breakwater in the port of Civitavecchia (Roma).

The PIVOT concept can be exploited in different configurations, by using alternative PTOs or by adapting the mobile and fixed structures to specific requirements. In particular, a system based on an oscillating floating



The PIVOT full-scale prototype (5 m width), in the wave tank of University of Naples "Federico II"

body is currently under development, in which the mechanical transmission of motion to the generator is achieved via an innovative system that reduces the criticalities deriving from the alternating wave-induced motion. The new configuration will be designed for both offshore and onshore installation, so as to expand the range of its possible uses, and to minimize the risk of disruption from extreme waves to which onshore plants are exposed. Future activities are expected to bring the PIVOT system to a higher TRL.



The E-WAVE 100 converter model

The E-WAVE 100 converter (TRL 4) for near-shore installation

The E-WAVE 100 converter consists in a dual chamber Oscillating Water Column (OWC) device, designed for being integrated into vertical wall breakwaters. The two chambers that constitute the device act in charge/discharge mode respectively, and are both equipped with specifically adapted non-return valves. In particular, wave motion causes sea water to rise to a level higher than the external mean sea level in the first chamber, which is equipped with free-flow valves allowing the free passage of the inward flux. Inside the second chamber, in its turn equipped with free-flow valves allowing the free passage of the outward flow, the water level is lower than the external mean sea level, and the resulting hydraulic potential generates the water flow in the duct that connects the two chambers. Electro-mechanic conversion is achieved via a low-head hydraulic turbine.

The E-WAVE 100 converter is characterized by minimum installation costs, low maintenance costs, scalability and modularity, as its simple structure can be constructed by using commercial components and materials that are easily available. A reduced scale (1:20) model was tested in the Aalborg University tank in 2017, while in 2018 the 1:2 model was tank tested in the Large Wave Flume (GWK) of Hannover University, in the context of the MARINET2 EU project.

The IMPETUS-UNIPA device (TRL 4) for near-shore installation

The IMPETUS-UNIPA device was developed and patented by the Department of Energy, Information Engineering and Mathematical Models (*Dipartimento Energia, Ingegneria dell'Informazione e Modelli Matematici - DEIM*) of the University of Palermo. It is a point absorber that consists in a cylindrical body containing a linear electric generator. The stator is integrated into an inner cylinder while the rotor is connected to an external cylinder that moves along with vertical wave motion.

The PM electric generator is an innovative device used to convert mechanical energy into electricity. This new technology offers the advantage of being free from any polluting additives, and can therefore be considered to be completely “clean”.

The ECOMar 100 wave energy converter (TRL 4) for near-shore installation

The ECOMar system by Kuma Energy is a Wave Energy Converter that can be integrated into any vertical structure and installed on any seabed. It is modular and can be upscaled from installation of a few KWh (e.g. small touristic harbours) to very large plants. ECOMar is a versatile hybrid system that combines a hydraulic and an electromagnetic converter, allowing energy production at both low and high frequency and for different wavelengths. It integrates a system for environmental monitoring, in order to automatically be switched off in case of extreme sea conditions, and is designed to be completely harmless for vessels adrift, as its floating body acts as a robust fender. ECOMar can be easily equipped with a system for the collection of plastic or other floating waste.

The ECOMar system is comparatively low cost, as it uses standard components that are easily available on the market, and it is designed to also minimize management and maintenance costs. A 1:8 prototype has been tank tested in the AM3 spin-off laboratory of the University of Florence, while a pilot plant is under development.

The SEASPOON device for off-shore applications (TRL5)

Seaspoon is an innovative submerged device designed for offshore applications. The system exploits the orbital trajectories of near-surface seawater motion, by automatically aligning its rotation axis with that of the orbit, perpendicular to that of wave propagation. Its depth can be modified according to the projected wave energy density, a characteristic that also allows protecting the device in case of extreme sea conditions.

The Seaspoon was patented by the Thermochemical Power Group (TPG), a spin-off of the Technical University of Genoa (Italian patent 1405004 GE2011A000020), after being tested in real sea conditions offshore Genoa. Future activities include the improvement of the electric generator, and are expected to bring the device to TRL 6-7.

RELEVANT NATIONAL EVENTS

Both the PELAGOS and MAESTRALE Interreg Projects (both already presented in the 2017 Report, <https://pelagos.interreg-med.eu/>, <https://maestrale.interreg-med.eu/>) implemented pilot actions at both regional, national and transnational level, aimed at easing the involvement of Small and Medium Enterprises (SMEs) in the marine energy sector and at developing a strategy for the deployment of maritime energy in the Mediterranean area.

In particular, PELAGOS organized:

- a Capacity Building Workshop entitled “Energie Rinnovabili Marine: Progresso tecnologico, prospettive e trend nel mercato delle tecnologie pulite” (“Marine Renewables: technological progress, perspectives and trends in the market of green technologies”), which was held in Rome, 17 April (http://www.enea.it/it/sequici/events/pelagos_17apr2018/energie-rinnovabili-marine);
- a workshop on the environmental impacts of marine renewables and on marine spatial planning, coastal zone management social acceptance, entitled “Energie rinnovabili marine: Innovazione tecnologica e protezione dell’ambiente nell’ambito della pianificazione dello spazio marittimo per un uso complessivamente sostenibile delle risorse marine” (“Marine Renewables: technological innovation, and environmental protection in the framework of Marine Spatial Planning for an sustainable overall use of resources), held in Rome on 5 October;
- an international B2B Event for enterprises active in the sector of marine renewables (“Match-making Blue Energy actors”, <https://pelagos-2018.b2match.io/page-2401>).

In addition, the Blue Energy Cluster Web Platform (<http://be-cluster.eu/>) has been launched, aiming to provide continuous and sustained support to organizations and enterprises that are active in the field of marine renewables or intend to explore the opportunities it offers.

On the other hand, the MAESTRALE Project organized a number of international events in several locations abroad, which are listed on the Project website.



The SEASPOON device

MEXICO

A programme for the implementation of the Technological Roadmaps for ocean energies published in 2017 by the Ministry of Energy is being continually updated as technological developments take place and public policies are improved.

OVERVIEW

A programme for the implementation of the Technological Roadmaps for ocean energies published in 2017 by the Ministry of Energy is being continually updated as technological developments take place and public policies are improved. In line with the programme, a theoretical assessment of wave, current, saline gradient and thermal gradient energy resources in Mexico has been elaborated by CEMIE-Océano. Extending the off-grid access to electricity is among the objectives of developing ocean energy in Mexico. Another objective concerns clean energy materials challenges (e.g. superhydrophobic, nanostructured ceramic and polymeric coatings). Progress has been made in the instrumentation of two natural laboratories, in the development of prototypes, materials and technical bases for environmental and social regulation. Joint projects have been approved to optimize resources for the use of marine bioenergy and offshore wind energy.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

Short- and medium-term goals have been set for the generation of electricity from clean energy sources. The Energy Transition Law (LTE) establishes a minimum share of clean energy in electricity generation of 25% by 2018, 30% by 2021 and 35% by 2024.

To strengthen the operation of the Mexican Energy Innovation Centres (CEMIEs), the Technological Roadmap (TRM) for ocean energy is focused on strengthening the technological capabilities required, including infrastructure, specialized human resources and technological services. It also prioritizes the actions required to reach the 2030 goals for installed capacity, as well as detailed activities, identification of stakeholders, targets and milestones in a specific timeframe. In 2018, the incorporation of wind offshore and marine bioenergy to CEMIE-Océano was approved; it is now therefore estimated that Ocean Energy can contribute 500 to 1000 MW of installed capacity by 2030.

The main National Priority Actions for ocean energy are training and capacity building, development of the regulatory frameworks for ocean renewable energy and development of innovative technologies. The approximate budget of the CEMIE-Océano for 2008 was around €5 million.

MARKET INCENTIVES

Mexico has introduced Clean Energy Certificates available to those companies which produce a certain amount of clean electricity or do not produce CO₂ emissions, as defined in Article 3, section XXII of the Electricity Industry Law, (ocean energy section). By 2019, it will be obligatory for all the companies that generate energy to have obtained or

bought these clean energy certificates to the value of at least 5.8% of the total national energy consumption. This figure is expected to increase to 7.4% by 2020, 10.9% by 2021 and 13.9% by 2022.

Currently, the Ministry of the Environment and Natural Resources (SEMARNAT) is preparing a carbon market. The aim is to create a national and international mechanism to benefit low carbon initiatives. However, time is needed to see how this market interacts with clean energy technologies.

PUBLIC FUNDING PROGRAMMES

The Fund for Energy Transition and the Sustainable Use of Energy was created by the Ministry of Energy (SENER) and the National Science and Technology Council (CONACYT) to promote and support projects and initiatives which contribute to the fulfilment of the National Strategy for Energy Transition and the Sustainable Use of Energy. The objectives of this fund are to:

- promote, encourage and disseminate the use and application of clean energy;
- promote the diversification of primary sources of energy;
- establish a standardization programme for energy efficiency;
- promote and disseminate measures for energy efficiency, as well as for saving energy;
- propose the necessary measures so that the population has access to reliable, timely and easily accessible information regarding the energy consumption of equipment, devices and vehicles, which operate with electricity.

This fund is intended to develop the national energy sector in energy efficiency, renewable sources, use of clean technologies and diversification of primary sources of energy through:

- 1) Capacity building:** develop scientific, technological and innovation capacities in academia, industry, society and government; promote the link between the stakeholders from the energy sector;
- 2) Research, development and innovation:** Identify and prioritize technological development opportunities and promote research to transfer this into commercial applications;
- 3) Training:** Promote the coordination and information acquisition for timely decision-making; assist in the training of personnel to encourage them to apply and generate knowledge, products and services of high value and; ensure that the energy sector attracts talented individuals;
- 4) International agenda:** Promote international collaboration in the programmes, projects and activities of the funds.

RESEARCH & DEVELOPMENT

Main R&D activities conducted by CEMIE-Océano:

The Wave Group has been working on the development and laboratory testing of five wave energy converters; the installation of equipment in a Natural Laboratory in Bahía de Todos Santos is continuing; the evaluation of wave power availability in Mexican waters; a database is under construction, with in situ data and numerical model; a Blow-Jet and a floating mono-buoy WEC devices have been numerically tested; a 3D wave tank has been designed and the buildings completed, and; a series of projects “Physical Modelling in Large Infrastructure” were approved in a collaboration with institutions from Spain, Germany, Uruguay, Costa Rica and Dominican Republic.

The Tidal and Current Group has been carrying out numerical modelling evaluations of tidal and ocean current energy, thus identifying two regions where harvesting this type of energy is feasible: the northern Gulf of California, and the northern Mexican Caribbean. There are also seasonal maxima at other sites which could be harnessed in the Pacific (Baja California), and associated with the Campeche Bank cyclonic gyre. Measurements are needed to verify this in other regions of the country. Technical challenges have arisen since some of the most attractive sites in the Caribbean (strong, persistent and unidirectional currents) are where slopes are abrupt, or depths are large, despite its closeness to the shore.

The Salinity Gradients Group is working on the electricity conversion by the RED technique (open and closed systems, both using Excellion membranes). The development of prototypes to obtain energy from salinity gradients is being promoted, exploring the use of new materials in the design and generation of membranes. Temporal and spatial variations of the naturally occurring salinity gradients hypersaline coastal lagoons and river mouths in Mexico are being intensively quantified.



The Ecology Group has been working on the following: a diagnosis of potential ocean power generation zones, based on the geomorphological characteristics of the coast; generation of information on the structure, composition and functioning of coastal and marine ecosystems and species, to determine the potential socio-environmental impact of the installation of new energy generating devices; inventories of flora and fauna at the potential sites of ocean power generation, and; where the sites mentioned have very important environmental assets, including fragile ecosystems such as coral reefs and endangered species (vaquita and totoaba), an evaluation of the environmental consequences of harvesting this energy is urgent.

The Materials Group has been developing a new set of superhydrophobic and nanostructured ceramic and polymeric coatings for steel, as well as a nitriding process, which have proven to be successfully anti-corrosive. A new current energy device has been designed especially suited to the conditions of Mexican waters. The production of polymer matrix composite blades is underway and a magnetohydrodynamic energy generator prototype has

been built and tested; from the evaluation of this, a larger prototype is now under construction.

The Grid Interconnection and Energy Storage Group has worked in three main areas: I) Evaluation of theoretical and physical models of different ocean energy devices, which established the tensions required for the different ocean energy sources for its management or interconnection for a) high voltage offshore wind, b) medium voltage OTEC, tides and waves; c) low voltage salt gradient, waves; and d) micro-networks all ocean energies, including on-site storage and consumption systems for specific services such as lighting or cathodic protection; II) Establishment of the battery storage limits for each of the above groups, some of which include the design of the marine device.

As a result of the investigations we have a technology to focus wave energy in specific points (TLR 4); an energy-independent WEC, for cathodic protection (TLR 6); an energy-independent WEC for lighting (TLR 6); an energy-independent WEC of 0.5 kW (TLR 6); an energy generator with marine algae biomass (TLR8); and development of super-hydro-phobic and super-hydrophilic coatings technology (TLR 3).

TECHNOLOGY DEMONSTRATION

PROJECTS IN THE WATER

CEMIE-Océano continues to conduct studies and to acquire and deploy oceanographic measuring equipment in order to recommend natural sites for testing wave energy devices in Ensenada, Baja California, and another to test ocean current energy devices in the Cozumel Canal, Quintana Roo.

A 5 kW OWC with a Wells turbine has been in operation since September 2018 in the Bay of Acapulco.

PLANNED DEPLOYMENTS

CEMIE-Océano has two projects with installations planned soon:

- Wave energy device – Sauzal Port, Baja California
- Ocean current turbine – Cozumel Channel

RELEVANT NATIONAL EVENTS

- Advanced course by CEMIE-Océano. Ocean Surface Wave Dynamics and applications into Energy Conversion. Department of Physical Oceanography, Ocean Division, CICESE, 21-31 August 2018
- Special session organized by CEMIE-Océano. International Conference on Sustainable Energy & Environmental Protection, SEEP 2018. University of the West Scotland, Glasgow, UK, 8-11 May 2018
- Several training courses for the formulation, administration and management of R&D,I projects and training courses for the creation and management of technology-based companies.

NETHERLANDS

A spatial analysis of the potential of the North Sea with a view to 2050 has been made, with regard to offshore wind, seaweed and ocean energy.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The Netherlands does not have a national strategy for ocean energy and nor are there specific targets. The ocean energy strategy is part of the national target of 16% renewables in 2023 and a 49% overall CO2 reduction in 2030.

The marine spatial planning is focused on offshore wind, special areas have been appointed for offshore wind (3500 MW). There are no commercial offshore ocean energy projects planned yet.

A spatial analysis of the potential of the North Sea with a view to 2050 has been made, with regard to offshore wind, seaweed and ocean energy.

The North Sea Spatial Agenda indicates a potential of up to 2000 MW of tidal current and wave energy to be possible, if techniques are developed further to fit the Dutch situation, with relatively low tidal heads and speeds. Although in some cases there is fast flowing water of estuaries, and near barriers there are places with high speeds up to 5 m/sec.

Although there is a central permitting system, in practise consenting requires engagement with a wide range of permitting bodies, such as central government, province, municipality, Rijkswaterstaat, local harbour authorities, Ministry of Defence and the regional water board.

The Netherlands' Department of Waterways and Public Works (Rijkswaterstaat) supports initiatives to generate energy, but on the other hand is responsible for protecting the Netherlands from flooding from the North Sea. In general, the current projects have been supported generously and erected quickly.

MARKET INCENTIVES

For 2019, the generic national subsidy scheme (SDE, stimulating renewable energy), has also been opened for tidal current, wave energy and free flow energy. The maximum subsidy for renewables has been reduced to €0,13/kWh, due to the decreased costs of offshore wind, which is considered as the benchmark.

Business and other organizations joined forces in DMEC, the Dutch Marine Energy Centre.

PUBLIC FUNDING PROGRAMMES

In addition to the above mentioned feed-in tariff (OPEX subsidy), there are generic funding programmes (CAPEX subsidy) for all relevant types of renewable energy. The Ministry of Economical Affairs initiated a number of grants via generic R&D instruments; these are also available for ocean energy research. These programmes have a tender system in which projects compete with each other, and have a general condition that a cost reduction must be achieved by innovation.

RESEARCH & DEVELOPMENT

SeaQurrent

In 2018, SeaQurrent further developed their tidal kite, aiming at moderate water speeds. The concept has been validated at the test facilities of MARIN. In 2019, SeaQurrent plans a first commercial demonstration project in the Wadden Sea, north of the Netherlands.

Redstack

Blue energy is energy generated from the difference in salinity between river water and sea water, for example at the point where a river naturally empties into the sea. According to Redstack, mixing 1 m³ of river water with 1 m³ of sea water can generate up to 0.5 kWh of electricity.

Reverse Electro Dialysis (RED) is a salinity gradient power technology that makes use of two types of membranes: one allows only positive ions to pass through, and the other allows only negative ions to pass through. Electricity can be generated by arranging these two types of membranes in a RED stack.

The amount of energy generated is related to the difference in salt concentration of the two solutions – the larger the salinity difference between the two solutions, the more energy can be generated. Blue Energy generates energy without producing CO₂, is easy scalable, 24/7 available and the only “waste” product is brackish water. Blue Energy is a perfect candidate for base-load energy production and application in the energy-mix.

After testing the technology at the pilot facility on the Afsluitdijk, Redstack now aims at a first demonstration plant in Katwijk (near The Hague), where the salinity gradient is optimal.

Tocado

In 2018, Tocardo further tested their 1.25 MW tidal power plant in the Eastern Scheldt.

Tocado is now planning a 2 MW successor, also consisting of 5 separate turbines.

Tidal Technology Centre

In 2019, after a delay of one season, the Tidal Technology Centre Grevelingendam plans to open its test facility. This test facility offers three differently sized channels for low head tidal turbines.

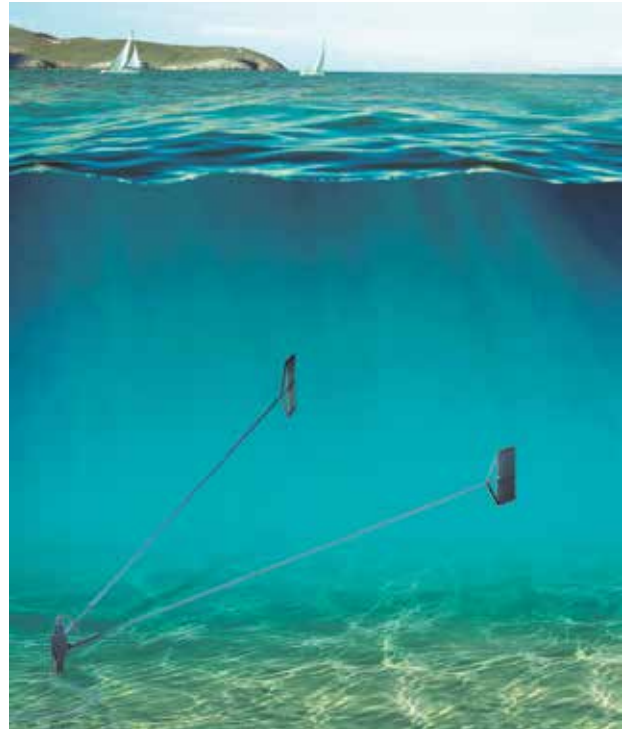


Illustration of the Tidal Kite from SeaQurrent



Redstack pilot facility



Tocado tidal power plant in the Eastern Scheldt (Photo credit: Tocardo Tidal Power)

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

Main developments in test sites during 2018:

OPERATIONAL PROJECTS

Tocado, 1.25 MW tidal power plant in the Eastern Scheldt, has been operational since 2015.

PLANNED DEPLOYMENTS

- OTEC Pilot Curacao (500 kW), Bluerise Delft
- OTEC Pilot/Demo Martinique, Artec power
- Tidal Test Centrum Grevelingen Barrier; several techniques
- Follow up of Tocado in Eastern Scheldt; 2 MW
- Brouwers Barrier tidal range plant (after 2019, various scenario's)
- Several arrays in Afsluitdijk discharge gates (further future)

RELEVANT NATIONAL EVENTS

The 4th annual Marine Energy Event was organized in cooperation with the Dutch Energy from Water Association (EWA) and the Dutch Marine Energy Centre (DMEC) at Amsterdam RAI on 24 October, focusing on wave, tidal, ocean thermal and salinity gradient technologies.

Test Site Name	Location	Promoter/ manager	Grid Connection	Status (operational, under development, planned)
Tidal Test Centre (TTC)	Den Oever	Tocado	0.3 MW	Operational
BlueTec floating platform	Texel Island	BlueWater	0.1 MW	Operational
REDstack	Afsluitdijk	REDstack	4-50 kW	Operational
Tidal Test Centre (TTC)	Grevelingen barrier	Pentair Fairbanks Nijhuis	1 MW	Under development, planned in 2019

NEW ZEALAND

There is increasing focus in New Zealand on the requirement for the electrification of industry and transport, and the consequent increase in electricity demand to be met from sustainable sources. Such demand is likely to be met in the short term by geothermal, wind, and solar, but ocean energy remains as a medium term prospect.

OVERVIEW

There is increasing focus in New Zealand on the requirement for the electrification of industry and transport, and the consequent increase in electricity demand to be met from sustainable sources. Such demand is likely to be met in the short term by geothermal, wind, and solar, but ocean energy remains as a medium term prospect.

Within the private sector, EHL continue to develop the Azura Wave device, conducting a second deployment in Hawaii in 2018.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

New Zealand does not have a specific national strategy for ocean energy, and the over-arching energy strategies outlined in the 2017 country report for New Zealand remain current. These strategies support the development of diverse energy resources, and seek to increase the use of renewable energy through the de-carbonization of process heat and transport.

Within this context, the state-owned national grid operator Transpower published a report in 2018 looking at NZ's energy future. This forecasts a doubling of NZ's

electricity demand by 2050 (relative to 2018), driven by the electrification of industry and transport. Electricity as a percentage of total delivered energy demand is therefore forecast to increase, from 25% to 60%. Marine energy is forecast to supply 5% of electricity generation by 2050, with most of the deployment forecast to occur in the 2040s.

Outwith this strategy, the most significant energy-related announcement in 2018 was a ban on new offshore oil and gas exploration. This was announced in April 2018 and passed into law in November 2018.

MARKET INCENTIVES

Market incentives for renewable electricity generation in NZ are relatively weak and are via the NZ Emissions Trading Scheme. This scheme requires all sectors of NZ's economy to report on their emissions and, with the exception of biological emissions from agriculture, to purchase and surrender emissions units to the Government for those emissions.

PUBLIC FUNDING PROGRAMMES

NZ has a number of Government funded R&D programmes, but none specifically targeting marine energy.

RESEARCH & DEVELOPMENT

Brett Beamsley of MetOcean Solutions, and Ross Vennell of the Cawthron Institute, are developing a software tool for the prediction of the physical oceanographic effects of large scale tidal current generation. This project is due to conclude in 2019.

TECHNOLOGY DEMONSTRATION

PROJECTS IN THE WATER

NZ-based Energy Hydraulics (EHL), in partnership with US-based NWEI, conducted a second deployment of the Azura Wave device at the US Navy's Wave Energy Test Site in Hawaii during 2018. This was a continuation of the testing conducted during 2015-17, with the focus of the 2018 deployment being to test a new float/arm design, and the incorporation of a heave plate. These in-sea tests of a reduced-scale design have informed the development of a full-scale design, which has also been modelled in WEC-SIM, and tested at scale in a wave tank.

PLANNED DEPLOYMENTS

EHL and NWEI have secured a further US\$4 million of grant funding from the US DOE to support the development of a full-scale commercial device. This funding is contingent on a further US\$4 million of matched funding, which is currently being sought from sources including the NZ Government.

NORWAY

Consultancy meetings have been held with the Ministry of Petroleum and energy in connection with the Ocean Energy Act (Havenergilova), taking effect through the implementation of secondary legislation.

OVERVIEW

Consultancy meetings have been held with the Ministry of Petroleum and energy in connection with the Ocean Energy Act (Havenergilova), taking effect through the implementation of secondary legislation.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

Offshore power production is to be regulated through the Ocean Energy Act, which is expected to have secondary legislation enacted by year's end. Additionally, expectations are for offshore power production, including wind power, to be connected to facilities connected to the oil and gas extraction on the Norwegian shelf; that means additional regulation from the oil and gas sector may come into play.

Norwegian ocean energy is under the domain of the Ministry of Petroleum and Energy. Under the Energy Act, the Norwegian Water Resources and Energy Directorate (NVE) was the relevant regulator – expectations are for this to remain as the Ocean Energy Act is being fully implemented.

The Norwegian Government has not implemented a coherent ocean energy programme. A “strategy for floating offshore wind” has been published, but it does not contain any specific targets, or overreaching support and incentive structures.

MARKET INCENTIVES

Since 2012, Norway and Sweden have been in a joint green certificate market. One certificate per MWh has since 2012 been given to all new renewable energy generation for 15 years, independent of technology. From year 2022, Norway will no longer participate in the scheme, while Sweden will increase their target build-out under the scheme with 18 TWh by 2030.

Norwegian energy production that may be certified for certificates until 31.12.2021 in the so-called transitional scheme; however, Norwegian projects will receive certificates only until 31.12.2035, even if the project is approved for certificates under the transitional scheme.

PUBLIC FUNDING PROGRAMMES

The Norwegian Energy Agency, Enova offers capital grants for full scale demonstration projects of ocean renewable production. While up to 50% of eligible costs can be covered, Enova's funding measured in absolute figures is limited. In addition, Enova has a programme that supports demonstration of new energy technology, on the basis that the technology is applied in Norway.

Innovation Norway runs a programme supporting prototypes within “Environment friendly technology”. Ocean energy is included in this definition. Projects are supported with up to 45% of eligible costs.

The Research Council of Norway runs an energy research programme called ENERGIX. This programme supports R&D within all renewable energy technologies.

RESEARCH & DEVELOPMENT

Stadt Towing Tank (STT) was founded in 2007 to deliver test and research services to the marine industry. The main market for STT has been ship designers in the maritime cluster of north-western Norway, but projects related to renewable energy are also tested. Among the renewable energy project has been wave energy converters, windmill installation concepts, wind turbine foundation solutions and wind turbine service vessels.

TECHNOLOGY DEMONSTRATION

Runde Environmental Centre (REC), located on Runde Island on the Norwegian west coast (<http://www.rundecentre.no>), can accommodate WEC plants for test and demonstration at several sites. One has a 3 km/0.5 MW sea cable to shore with grid connection. REC facilitates preparations, licensing, deployment and monitoring of the WECs, and works also on other forms of ocean energy, building national competence and capacity.

REC hosts other sub-sea tests, for anti-corrosion and anti-fouling. In 2016, a new bathymetric dataset, with 1x1 m resolution was released by REC, for public use. This unique material is very useful when it comes to licensing and siting

of OE devices in the area. The same applies to the wave forecasting model installed, in co-operation with the Norwegian met office.

PROJECTS IN THE WATER

The first operational, grid connected wave energy buoy project in Norway was launched on 2 June 2017. The Swedish technology company **Waves4Power** has developed and produced a 100 kW energy converter, which is currently undergoing long term grid connected testing at the Runde Environmental Centre (REC). The anchored buoy, Wave-EL, is connected to a stand-alone buoy-mounted transformer. The transformer is readied for additional 9 connections, and so a powerplant-sized future demonstration is technically feasible.

Fred Olsen BOLT Lifesaver is undergoing a second round of tests at the US Navy's Wave Energy Test Site (WETS) on Hawaii, to power an oceanographic sensor package.

PLANNED DEPLOYMENTS

Norwegian Ocean Power has been developing a tidal device using a Darieus-turbine H300A of 300 kW and they have now permission to install their prototype in Lofoten.



Runde Environmental Centre (REC) at Runde Island on the Norwegian west coast (Photo credit: Per Eide)

PORTUGAL

In 2018, WavEC, IST, INEGI, University of Algarve and other Portuguese Universities, public and private entities were active partners in national or international research efforts on ocean energy.

OVERVIEW

In 2018, WavEC, IST, INEGI, University of Algarve and other Portuguese Universities, public and private entities were active partners in national or international research efforts on ocean energy. The granting support by the Blue Fund (Fundo Azul), a new national funding scheme launched in 2017, aimed at developing the blue economy, has been announced during the year.

There has been continuous progress with the oscillating water column and air turbines, following decades of research in Portugal with this type of wave energy technology and its power take-off. A new turbine prototype has been tested in one of the OWCs of the Mutriku breakwater and further on a floating OWC prototype in the Basque country, at Bimep.

AW-Energy continues active in Portugal, progressing with its project to be installed in Peniche.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

In Portugal, the Ministry of the Sea is responsible for defining policies encouraging the development of new activities in the sea that maximize the use of its resources, generating economic value in a sustainable model. In this sense, the Government programme has a medium- and long-term strategy for the use of the resources of the sea, in which renewable marine energy (wave and offshore wind) is of special relevance.

Portugal's Industrial Strategy for Ocean Renewable Energies (EI-ERO) was published in 2017 and is based on two main goals: to stimulate export and value added investment and to assist industry in reducing risks. The corresponding action plan defines that business opportunities in wave energy for Portugal should focus on having the right conditions for attracting R&D investment, in terms of infrastructures and financing. At national level it is estimated that there is a potential between 3 and 4 GW, considering other uses of the sea. The approach to the wave energy market is pursued in three stages: (i) technology development and demonstration by 2022; ii) pre-commercial development between 2023 and 2028; and iii) commercial maturity, with significant activity in 2030.

MARKET INCENTIVES

In Portugal, electricity from renewable sources from plants registered until 2012 is mainly promoted through a feed-in tariff (FiT). Since 2012 no guaranteed remuneration scheme has been approved for new projects.

PUBLIC FUNDING PROGRAMMES

Foundation for Science and Technology (FCT)

The funding of the Portuguese research system is mainly conducted through the Foundation for Science and Technology (FCT), under the authority of the Ministry of Science, Technology and Higher Education. FCT has been funding research on ocean energy via the Ocean Energy European Research Area Network (**OCEANERA-NET**)

programme. This was a network of 15 national and regional funders of research and innovation programmes, from 8 European countries, which have received funding from the European Union under the Horizon 2020 Programme for R&I and ended in February 2018.

Of the ten projects approved by OCEANERA-NET, FCT funded the participation of Portugal in 8 projects listed below, running until 2018, of which the first 3 were coordinated by Portugal (WavEC, IST and INEGI):

- **KRAKEN:** Portugal (WavEC and IST), Spain and Ireland
- **ELASTMOOR:** Portugal (IST) and Sweden
- **SE@PORTS:** Portugal (INEGI, UPorto, APDL, FORUM OCEANO), Spain and Belgium
- **CAPTWO:** Ireland, Spain and Portugal (Cruz-Atcheson Consulting Engineers and IST)
- **MIDWEST:** France, Sweden, Denmark and Portugal (IST)
- **OCEANIC:** Sweden, Spain and Portugal (WavEC)
- **RECODE:** Spain, Ireland, UK and Portugal (WavEC)
- **TUPPERWAVE:** Spain, Ireland and Portugal (WavEC)

Built on the work of this programme, the Ocean Energy ERA-NET Cofund (**OCEANERA-NET COFUND**) was initiated, operating from 2017 to 2021, also supported by the EU's Horizon 2020 Programme, involving the participation of 8 national and regional government agencies from 6 European countries. The participating countries/regions are: the Basque Country, Brittany, Ireland, Pays de la Loire (France), Portugal, Scotland, Spain and Sweden. The aim is to coordinate support for research and development in ocean energy, to encourage collaborative projects that tackle some of the key challenges identified for the sector as it progresses towards commercialisation. The national funding commitment for the next call (5 April 2019) is €300.000 with a maximum requested funding for each project with Portuguese participation or coordination of €150.000.

Sea Policy General Directorate (DGPM) - BLUE FUND

In 2018, the Sea Policy General Directorate (DGPM) announced the results of the call Blue Fund for the topic Ocean Renewable Energy – “Leading Wave Energy Research” aiming to fund research and development projects on demonstration prototypes for wave energy systems and/or components. The budget allocated for this call reached a total amount of €1.000.000 with a maximum grant per application of € 200.000.

Blue Fund is an innovative public financial instrument, managed by the Ministry of the Sea, which started in 2017 focused on the development of the ocean economy, scientific research and protection of the sea environment. It prioritizes the development of sea biotech start-ups,

underwater robotics, innovative shipbuilding, ocean energy, aquaculture technology and innovative solutions for ocean protection, safety, monitoring and surveillance.

Six projects have been approved for wave energy demonstration projects and robotic equipment for operations in the sea, led by the following Portuguese institutions: WavEC, IST, inanoEnergy (University of Porto), In2sea, Composite Solutions and Abyssal.

National Innovation Agency in Portugal (ANI)

Portugal 2020 framework programme is organized into four thematic domains, one of which is dedicated to Sustainability and the Efficient Use of Resources. The global budget for this programme running until 2020 comes from the European Structural Fund aiming to stimulate economic growth and job creation in the country. Within this framework, the Competitiveness and Internationalization Operational Programme (Compete 2020) opens call for all sectors without distinction, not address specific levels of technological readiness. Ocean energy demonstration projects can apply to this programme, managed by the National Innovation Agency in Portugal (ANI).

RESEARCH & DEVELOPMENT

WavEC Offshore Renewables

WavEC is a private non-profit organization with a strong research and innovation component and a broad spectrum of specialized services in Marine Renewable Energies and Engineering Solutions for the ocean economy, incorporating technological, economic, environmental, social and legislative aspects.

Following is a list of selected R&D projects on ocean energy, running in 2018, in which WavEC has been involved:

In 2018, **WETFEEET**, an European funded project of the H2020 programme led by WavEC, was concluded. This three-year project with a total funding of €3.5millions comprised teams from Austria, France, Italy, Portugal, the Netherlands and the United Kingdom. Using as a starting point the identification of the major constraints that have been delaying wave energy's progress, WETFEEET analysed key pressing issues (technical, economic, financial and environmental) that need to be addressed in order to improve the whole sector. More information at: <http://www.wetfeet.eu/>

In late 2018, three new European funded projects were approved, ETIP Ocean2, an European Technology and Innovation Platform for Ocean Energy, funded by H2020 and BLUEGIFT funded by Interreg Atlantic Area Programme. This last one, managed by EMEC, will give the opportunity to promote open sea testing in Portugal.

Project	Funding Programme	Duration	Description
RECODE	Oceanera-NET	2015 – 2018	To develop, demonstrate and validate standardized components that will contribute to lower ocean energy technology deployment costs.
OCEANIC	Oceanera-NET	2015 – 2018	Developing systems for surfaces protection to provide the Ocean Energy sector solutions to improve its reliability and project's life time.
WETFEET	H2020	2015 – 2018	WETFEET has the overall aim to understand and find solutions to the constraints of wave energy technology (coordinated by WavEC).
WAVEBOOST	H2020	2016 – 2019	To develop an Advanced Braking Module for Wave Energy Converters to be built and tested on the platform of the existing CorPower technology.
MARINET2	H2020	2017 – 2021	Network of leading European research infrastructures and facilities specialising in R&D for offshore energy.
MARINERGI	H2020	2017 – 2019	To become the leading internationally distributed infrastructure in the Marine Renewable Energy sector.
MEGAROLLER	H2020	2018 – 2020	To build and validate a PTO solution for oscillating wave surge converter (OWSC) designs, to be tested on the Waveroller technology.
SEA-TITAN	H2020	2018 – 2020	To build and validate a PTO solution for multiple types of wave energy converters, tested with the Wello technology.
DTOCEANPLUS	H2020	2018 – 2021	To develop advanced design tools for ocean energy technologies.
WESE	EASME	2018 – 2021	To develop environmental monitoring on wave energy converters operating at sea, in Southern Europe.
BLUECAO	Fundo Azul (national funding)	2018 – 2020	To develop an offshore platform to supply energy and feed offshore aquaculture based on wave energy converters (coordinated by WavEC)

Pico Plant

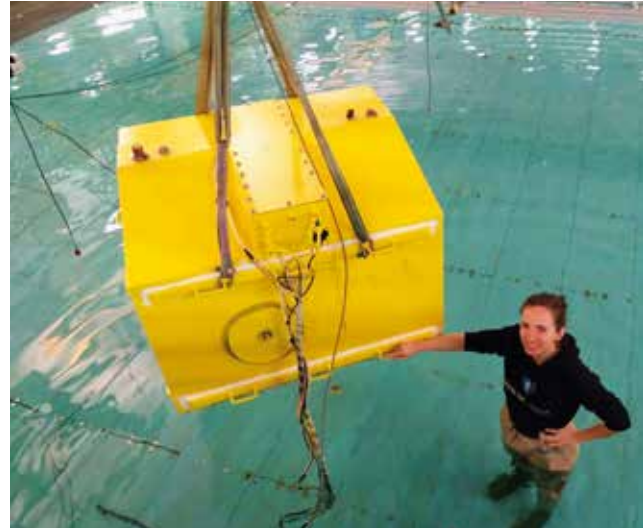
Pico Wave Power Plant, at Azores, Pico, run by WavEC, was disconnected from the network on April 17, 2018 due to the partial collapse of the plant. The project to dismantle the plant had already been started, being prepared by both Portuguese utilities, EDA and EDP.

Pico Plant has made a very valuable contribution to the promotion of wave energy research, development and innovation, both at national and European level and internationally, attracting more than 11 national and European projects. Pico Plant was part of two European networks of test infrastructure for wave energy technologies (MARINET AND MARINET2), promoting the access of international teams to the plant. The plant originated more than 100 international scientific articles and was associated with more than 8 doctoral theses and numerous master's theses and scientific internships.

In 2018, a book with the story of the plant and testimonies from those that visited or worked at the plant was published by WavEC, in Portuguese language:

<https://www.wavec.org/contents/reports/brochura-central-do-pico-2018.pdf>





Biradial turbine installed on MARMOK-A-5 spar-buoy OWC, at Bimep, Basque Country, October 2018 (left). Model of UGEN at the wave tank of Plymouth University, UK (right).

INSTITUTO SUPERIOR TÉCNICO

Two groups were active on ocean energy at Instituto Superior Técnico (IST):

- **Institute of Mechanical Engineering (IDMEC)** with decades-long history in wave energy conversion studies;
- **Centre for Marine Technology and Engineering (CENTEC)**, whose involvement in ocean energy is more recent.

Following previous years, the activity at IDMEC concentrated on wave energy conversion, especially the development of new types of oscillating water column converters (OWCs) and self-rectifying air turbines. An important area of research at IDMEC is latching control of floating and fixed-structure OWC converters, taking advantage of new types of air turbines fitted with fast valves.

IDMEC/IST was a partner in the WETFEET project coordinated by WaVEC (European H2020 programme) that terminated in May 2018; in 2018 the involvement of IDMEC/IST concerned mainly the development of a multipurpose platform made of OWCs wave energy converters that has been tested at 1:40 scale at Plymouth University. IDMEC/IST is also a partner in the OPERA project (H2020), in which, jointly with the Portuguese company Kymaner, designed a prototype of the biradial self-rectifying air turbine with a new type of fixed guide vanes and a fast valve. The turbine prototype was supplied by Kymaner, and was installed at one of the OWCs of the Mutriku breakwater (Basque Country, Northern Spain), where it was operated under real sea conditions until July 2018. In October 2018, the turbine-generator set was installed on the MARMOK-A-5 spar-buoy OWC of the Spanish company Oceantec/IDOM, and is operating at the BiMEP test site (Bay of Biscay, Northern Spain).

Another wave energy converter concept has been under development at IST: the UGEN, a floating device with an

interior U-shaped oscillating water column and a self-rectifying air turbine. A 1:24 scale model was tested in 2018 at the wave tank of Plymouth University, UK, within the framework of the European programme MARINET 2.

Ocean energy is a major area in the diversified activity of CENTEC/IST. The activities at CENTEC in ocean energy involved a wide range of topics covering waves, tidal currents and offshore wind. The characterization of the wave energy resource (and to a much lesser extent tidal and offshore wind energies) at various oceanic locations in the world has been one of the dominant topics. The study of ocean energy conversion focused mainly on wave energy converters, with numerical theoretical/modelling and model testing of several types of devices and arrays, and also PTOs (namely hydraulic-circuit PTOs).

University of Algarve

At University of Algarve there is one active group on tidal current energy, the **Marine Offshore Renewable Energy (MORE)** team, which has been involved in the following three projects:

- **OpTiCA – Optimisation of Tidal Energy Converter Arrays:** a 2-years project funded by H2020 that aims to provide a significant contribution towards the understanding of (a) the effects of Tidal Energy Converters (TECs) interactions with the environment; (b) the capabilities and limitations of common strategies used for the numerical modelling of TECs; and (c) how to mathematically formulate optimisation models to solve the TEC array layout problem considering technical, socio-economic and environmental constraints. This project is led by the Marine Offshore Renewable Energy (MORE) team from the University of Algarve (<https://www.msca-optica.eu>).
- **SCORE - Sustainability of using Ria Formosa Currents On Renewable Energy production:** this project funded by the national Foundation for Science and Technology (FCT) started in 2016 and will run for 3 years. The

general objective of SCORE is to examine a small scale tidal current turbine Evopod E1 (1:10th scale), from UK-based tidal energy developer Oceanflow Energy, to be deployed in a shallow-water estuarine environment at Ria Formosa, a coastal lagoon in the south of Portugal, looking at both the impacts of the turbine on its environment and the effects of the flow conditions on the turbine (<http://w3.ualg.pt/~ampacheco/Score/aboutscore.html>)

- **MONITOR - Multi-model Investigation of Tidal Energy Converter Reliability:** a 3-years project funded by the European funding programme INTERREG Atlantic Area, that started in 2017, led by Swansea University, whose objectives are to investigate the reliability of tidal energy converters and develop tools to increase it. The roles of the University of Algarve are: 1) to plan and coordinate field work activities from two full scale tidal turbine deployments: Sabella D10 at Passage du Fromveur (France) and Magallanes Renovables' ATIR platform at EMEC (UK); 2) to collect and process the resulting data; and 3) to publish the findings in a suitable format (<https://www.monitoratlantic.eu/>).

INEGI - Institute of Science and Innovation in Mechanical and Industrial Engineering

INEGI is an Institution at the interface between the University of Porto and the Industry, oriented towards the activities of Research and Development, Innovation and Technology Transfer. INEGI has been involved in nationally and internationally funded and subcontracted projects related to Marine Renewable Energy (mainly offshore wind and wave energy).

Since 2017 INEGI is coordinating the SE@PORTS project, funded by the national Foundation for Science and Technology (FCT) through the funding programme Oceanera-net. In addition, INEGI has been involved in a number of R&D projects related to sea activities mainly funded by the European Commission. Two new projects related to the ocean energy were approved during the year 2018:

- **I.nano.WEC:** a 2-year project, which started in May 2018, funded by the national fund "Fundo Azul", aiming to develop the first marine buoy prototype integrating highly efficient energy harvesting systems based on triboelectric nanogenerators. The coordinator of this project is the InanoEnergy (www.inanoe.com) which is a start-up company created in 2016 to develop, prototype and produce energy harvesting solutions with applications on the internet of things.
- **PORTOS:** a 3-year project, with start date scheduled to April 2019, funded by the European funding programme INTERREG Atlantic Area, aiming to develop and promote the implementation of renewable energy (RE), especially marine energies at ports in the Atlantic Area, targeting two environmental priorities for ports: reduction of greenhouse gases emissions and air pollution, by providing RE-based solutions to harvest the Renewable Energy potential of the Atlantic coastal areas. Moreover,

PORTOS aims to increase the energy efficiency of the ports, establishing a roadmap to a more competitive and sustainable sector, mitigating climate change. PORTOS project will be lead by the University of Porto.

TECHNOLOGY DEMONSTRATION

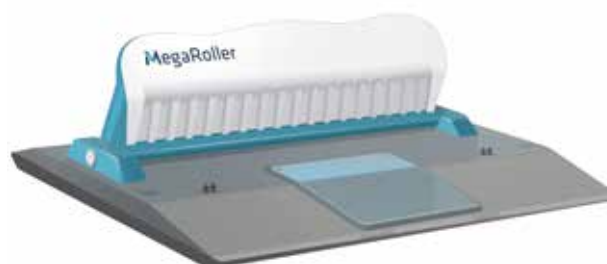
PLANNED DEPLOYMENTS

AW-Energy

AW-Energy has granted funding from the EU Horizon2020 programme (MegaRoller project) for development of a Power Take-Off unit for a 1MW device. The project started in May 2018 and will run until 2021, with a total of €5 million funding. Two Portuguese partners integrate the consortium, WavEC and Cruz Atcheson, with other partners from Finland, Germany and Norway.

WaveRoller is a submerged wave energy converter based on a hinged panel that is attached to the sea bed in the near shore area. It generates electricity from the movement of the waves (surge phenomenon) and is connected to the electric grid onshore.

AW Energy's First-of-a-Kind (FOAK) WaveRoller, which has been fully licensed in 2017, is currently in its final stage before deployment along the coast of Peniche, in Portugal.



MegaRoller concept (<https://www.sintef.no/MegaRoller>)

RELEVANT NATIONAL EVENTS

CENTEC/IST organized the **3rd International Conference on Renewable Energies Offshore** that took place in Lisbon on 8-10 October 2018 with about 150 participants. 101 papers were presented. The proceedings were published by CRC Press.

WavEC Offshore Renewables organised its **Annual Seminar 2018 on the challenges and opportunities in the offshore renewable and aquaculture industry** in collaboration with the British Embassy in Portugal. The event took place on 4 December 2018.

IST and WavEC have been involved, since 2013, in the **EUREC master course** in Renewable Energy, offering a one-semester specialization in ocean energy. This took place from February to May 2018.

REPUBLIC OF KOREA

The Ministry of Oceans and Fisheries (MOF) established the commercialization plan for ocean energy systems to contribute to the new national renewable policy to provide 20% of electricity from renewable sectors by 2030. To support this Ministry's plan, many R&D projects are being carried out.

OVERVIEW

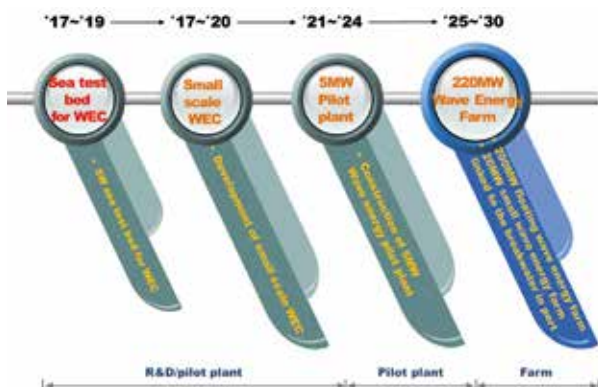
The Ministry of Oceans and Fisheries (MOF) established the commercialization plan for ocean energy systems to contribute to the new national renewable policy to provide 20% of electricity from renewable sectors by 2030. To support this Ministry's plan, many R&D projects are being carried out. Korea Research Institute of Ships and Ocean Engineering (KRISO) has been investigating small wave energy converters (WECs) of the oscillating water column (OWC) type integrated in breakwaters combined with an energy storage system (ESS) and connected to a micro-grid. The 300kW floating pendulum type WEC was grid-connected in 2018 and will be tested further. A tidal current and pumped hydropower combined energy conversion system has been developed and will be tested in the field in 2019. A 200 kW active-controlled tidal energy converter (TEC) was fabricated and tested onshore in 2018 and will be deployed in 2019.

Two open sea test sites for WECs and TECs are also being developed. Korea Wave Energy Test and Evaluation Centre (K-WETEC) managed by KRISO is now in its first phase of development (May 2016 - December 2019), and Korea Tidal Current Energy Centre (KTEC) established by Korea Institute of Ocean Science and Technology (KIOST) is under development (May 2017 - December 2022). A new international cooperation project between Korea and China was initiated to exchange technology development and utilization of ocean energy systems (2018-2020). As part of this project, the first China-Korea Symposium on Marine Energy was held in Zhoushan Campus, Zhejiang University with a technical visit to the test site for TECs on Zhairuoshan Island.

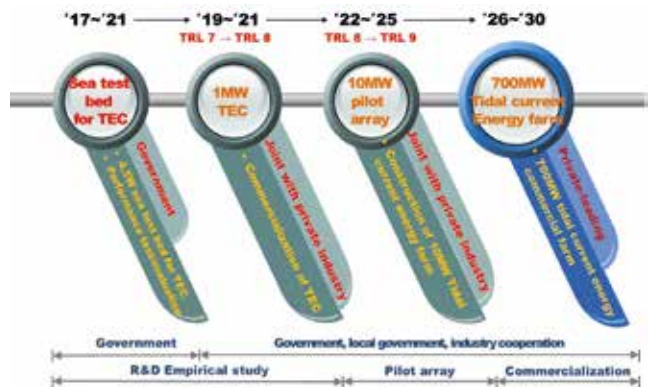
SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

Under the new Ministry's action plan of "2030 Ocean Energy Development Plan" for developing and disseminating the ocean energy systems, a strategic plan was established in the field of tidal and wave energy development. This plan is divided into four steps, including (1) expansion of R&D in ocean energy and establishment of open sea test sites, (2) construction of a large-scale ocean energy farm, (3) entering the global market and expanding domestic supply, and (4) the establishment of the ocean energy certification system and the supporting policy. The steps for commercialization for tidal and wave energy technologies are summarized in the following two figures.



Commercialization steps for wave energy technologies



Commercialization steps for tidal energy technologies

MARKET INCENTIVES

The renewable portfolio standard (RPS) was established in 2012 to enforce utility companies with the capacity of over 500 MW to provide an obligatory portion of the total electricity production with renewable energy based on the governmental policy, "Acts on the Development, Utilization and Supply Promotion of Renewable Energy". The market incentive plan, known as tradable Renewable Energy Certificate (REC), supplements the RPS policy. The value of REC is currently given as 2.0 for tidal current, 1.0 for tidal barrage with embankment and 2.0 for tidal barrage without embankment, whereas the value of REC for the wave and ocean thermal energy is not to be determined. Recently the value of REC for the

offshore wind has been increased from 2.0 to 2.0 – 3.5 according to the distance from coastal line to promote the offshore wind industry. However, the values of RECs for tidal energy were not increased.

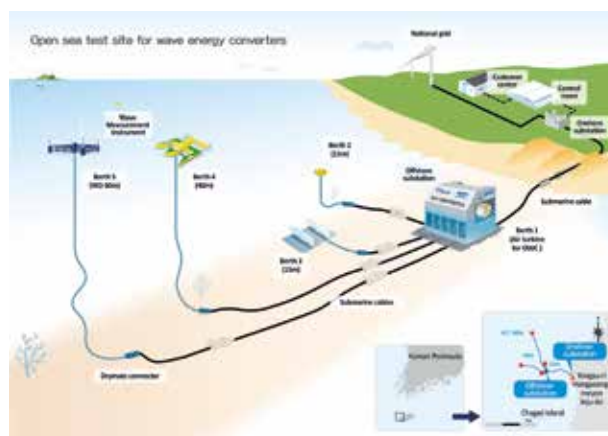
PUBLIC FUNDING PROGRAMMES

MOF provides public funding for ocean energy R&D projects including demonstration projects, and USD13.3 million was invested for the development of ocean energy systems in 2018. The annual budget for ocean energy R&D projects is planned to be USD16.2 million in 2019. Two new projects will be initiated to develop (1) 1 MW TEC and (2) TEC for remote islands with ESS will in early 2019.

RESEARCH & DEVELOPMENT

MOF has been supporting two construction projects of the open sea test sites for WECs and TECs. The construction project for WECs started in May 2016 and will be finished in December 2019. The western waters of Jeju Island were selected as the test site, and the existing Yongsoo OWC-type WEC is utilized as the first berth for OWC-type WECs and also as the offshore substation for the open sea test site. KRISO has been in charge of developing the project and the total budget is about USD17.3 million. Four more berths, two in shallow water in 15 m water depth and two in deep water in 40-60 m water depth, have been connected to the offshore substation and the grid system with the total capacity of 5 MW. The offshore cables were installed in 2018. The floating pendulum wave energy converter (FPWEC), with the capacity of 300 KW, was connected to the fourth berth with 40 m water depth in 2018. The fifth berth with 60 m water depth is expected to be used for floating offshore wind turbines as well.

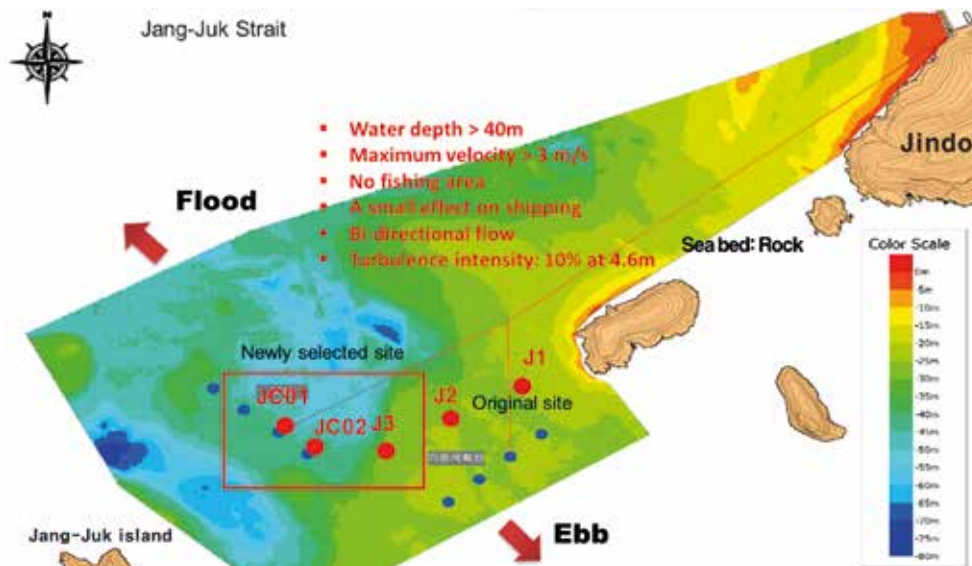
The construction project for open sea test site (i.e. Korea Tidal Current Energy Centre, KTEC) with 5 berths of 4.5 MW grid-connected capacity for TECs is being carried out from May 2017 to December 2022 by KIOST. Furthermore, the onshore performance test facilities for components of TECs, such as blade and drive train, will also be constructed in this project. The southwestern waters of the Korean Peninsula are primarily considered as the tidal energy test site, where the Uldolmok tidal current pilot plant (TCPP) is operating nearby. Uldolmok TCPP will be utilized as the test site for small and medium size TECs under 500 kW due to the limited water depth about 25 – 30 m. Several possible arrangements of test berths in JangJook Strait were studied in 2018, and a newly selected arrangement was confirmed to have better condition with sufficient water depth.



Open sea test site for wave energy converters



Installation of offshore cables nearby the existing OWC WEC



Possible two arrangements for 4 Test berths

TECHNOLOGY DEMONSTRATION

PROJECTS IN THE WATER

Floating Pendulum Wave Energy Converter

Since 2012, the development project for the 300 kW floating pendulum-type wave energy converter (FPWEC) has been carried out by KRISO with the support from MOF. The size of FPWEC is 23m(B) x 30.5m(L) x 10m(H), hydrostatic power transmission was used for PTO and connected to 300 kW and 11kV synchronous generator, and 4 point 8 lines catenary system was applied for mooring. The construction of FPWEC was completed in 2016, and the remote operating and monitoring system was tested and optimized in 2017. The FPWEC was installed at the fourth berth of K-WETEC and grid-connected in 2018.

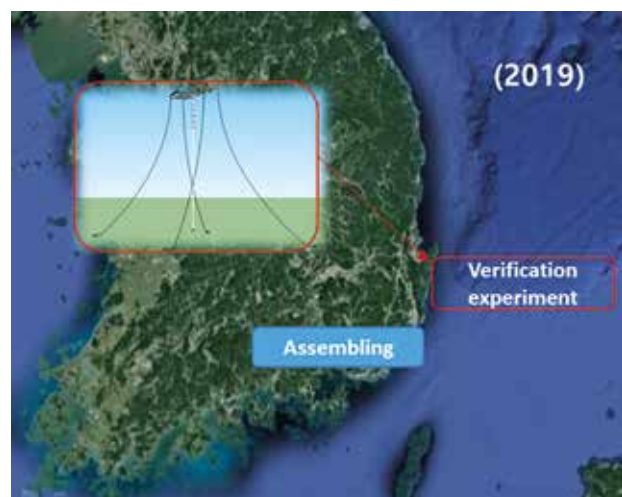
PLANNED DEPLOYMENTS

Active-Controlled Tidal Current Power Generation System

The project is aimed to develop and demonstrate the active-controlled, high efficiency and low cost 200 kW TEC, with the operating capacity applicable to the shallow sea conditions (about 20 m). The 200 kW TEC was designed and manufactured by KIOST and its caisson-type substructure was designed, fabricated, and deployed by Hyundai Engineering and Construction in 2016. The performance of PMSG and main drive train has been evaluated using a portable dynamo test facility, and the internal communication system and the active rudder device for automatic and passive yaw control has also been tested in indoor and underwater environments in 2017-2018. The installation of TEC was postponed due to the weather condition and it will be installed in the Uldolmok test site for open sea test in the early 2019.

1MW KRISO-OTEC

For the commercialization of the ocean thermal energy converters (OTECs), KRISO is in charge of developing a 1 MW OTEC demonstration plant. The plan is to complete the installation on a barge and perform the short-term operation in the eastern coast of Korea by 2019, followed by transferring and construction as on-land type to conduct long-term operation in South Tarawa, Kiribati, in 2020.



Locations for assembling and verification for 1MW OTEC PLANT

RELEVANT NATIONAL EVENTS

The Seventh International OTEC Symposium will be held in Busan, Korea, in 2019.

SINGAPORE

In 2015, Singapore pledged to reduce its Emissions Intensity (EI, or GHG emissions per unit of GDP) by 36 per cent from 2005 levels by 2030, and stabilise emissions with the aim of peaking around 2030. This makes the country more determined to establish different energy efficiency measures and to harness alternative sources of energy.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

Singapore is an islandic nation located in the heart of South East Asia with a total land area of about 721.5 km² and with a population of about 5.64 million as per data provided by the Department of Statistics Singapore in September 2018. In its Climate Action Plan released in July 2016, the Government devised four strategies to achieve a sustainable and vibrant low carbon economy: improving energy efficiency, reducing carbon emissions from power generation, developing and demonstrating cutting-edge low-carbon technologies, and through the collective action of the Government, individuals and businesses. In 2015, Singapore pledged to reduce its Emissions Intensity (EI, or GHG emissions per unit of GDP) by 36 per cent from 2005 levels by 2030, and stabilise emissions with the aim of peaking around 2030. This makes the country more determined to establish different energy efficiency measures and to harness alternative sources of energy.

MARKET INCENTIVES

The Green-e Renewable Energy Standard for Singapore allows Green-e Energy certification of renewable energy products throughout Singapore, in order to accelerate the development of renewable generation and renewable electricity markets, and to provide consumers with a meaningful mechanism through which they can express demand for renewable electricity (Green-e, 2017). Instead of subsidies, Singapore has taken proactive steps to introduce regulatory enhancements to facilitate the entry of renewable energy when such technologies become commercially viable (EMA, 2017). The Government's support for renewables mainly comes in the form of funding for Research & Development to develop capabilities within the industry.

PUBLIC FUNDING PROGRAMMES

More than S\$800 million public funding has been set aside by the Singapore Government for research in energy, water, green buildings and addressing land scarcity, of which S\$140 million is allocated for research into clean energy technologies under the banner of the Energy Innovation Programme Office (EIPO) (EDB, 2015). Ocean renewable energy has been identified as one of the prominent alternative energy by ERI@N specifically towards remote coastal and islandic region as part of its strategic research interests. The Government also welcomes clean technology companies to use Singapore as a 'Living Lab' to testbed and demonstrate innovative solutions before scaling up for the rest of the world. In 2017, the Singapore Economic Development Board (EDB) also secured investments from six clean energy companies worth \$500 million for next five years (EDB, 2017).

RESEARCH & DEVELOPMENT

ERI@N, supported mainly by the EDB, focuses on the areas of sustainable energy, energy efficiency infrastructure and socio-economic aspects of energy research. Its mission is to be a centre of excellence for conducting advanced research, development and demonstration of innovative solutions, which have both regional and global impact. The Institute has considerable expertise and strength in areas of offshore energy, which includes wind, wave and tidal energy and complementary technologies, such as energy storage, micro grids, and smart energy systems, and collectively provide an integrated set of expertise from materials design & synthesis, device fabrication and modelling, and systems integration and optimization.

ERI@N's Wind and Marine (W&M) research programme is aimed at improving the performance, lowering costs and accelerating deployment of offshore renewable technologies specific to the tropics, where unique technology challenges exist. It advances the technology development and commercialization through early collaboration with industry. It works closely with government agencies to understand regional needs, and with local and global renewable energy firms to identify technology gaps.

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

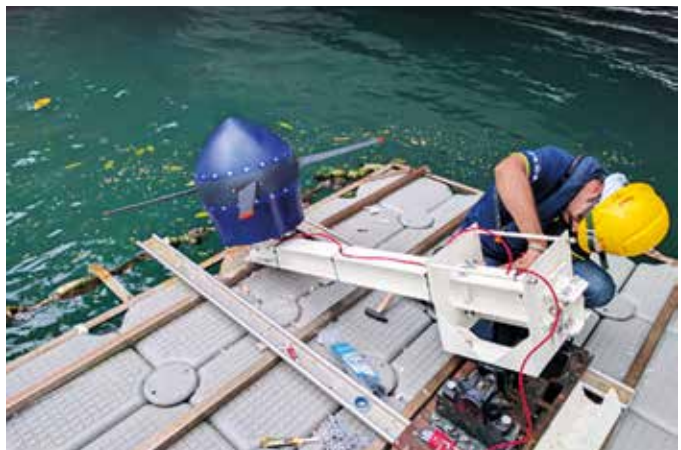
Sentosa – ERI@N Tidal Site

The Sentosa Tidal Test Site is a joint collaboration between Sentosa Development Corporation (SDC) and ERI@N, funded by the Ministry of Trade and Industry's Core Innovation Fund. This project aims to showcase tidal energy extraction as a feasible and sustainable energy generating technology in Singapore and to provide opportunities to develop local technologies to harness the energy available in the narrow channel between Singapore and Sentosa. In November 2013, ERI@N and SDC officially launched the Sentosa Tidal Test Site (NTU, 2013). Recent developments on the test site include the deployments of tidal turbines supported from the floating barges. Also, novel concepts such as anti-biofouling coatings are being evaluated for better field performance. The power developed is used for electric lighting on the boardwalk.

OPERATIONAL PROJECTS

Turbine Demonstration Project – MAKO Tidal Turbines

In June 2017, MAKO Tidal Turbines commenced research in collaboration with Energy Research Institute @ Nanyang Technological University (ERI@N) Singapore to evaluate the performance of its MAKO.4 tidal energy turbine in Singapore tropical water conditions. Singapore was selected by MAKO turbines because of its Government's active support for hosting and nurturing the development of renewable energy, availability of suitable tidal flow and its proximity to Asian markets. ERI@N tidal site was used for this turbine demonstration project. ERI@N was actively involved in this project in deployment and in evaluating the performance of the MAKO.4 tidal energy turbine. ERI@N also performed studies related to the impact of tropical environment on tidal turbine as well as on its performance.



MAKO.4 Tidal turbine which was demonstrated in ERI@N tidal site, Sentosa

Barge based floating tidal system

In the interest of promoting sustainable energy solutions to achieve energy security with reduced carbon footprint from tropical regions, the Energy Research Institute at Nanyang Technological University (ERI@N) works with international partners in developing and test bedding tidal in stream energy systems for island conditions with micro grids architecture. Recent developments include the deployment of scaled tidal turbines supported from the floating barges. Figure 2 shows the barge based tidal system which is further scalable to any site flow conditions to operate in any south East Asian country. The project was developed through a collaborative effort of Energy Research Institute at Nanyang Technological University (ERI@N) together with Schottel Hydro, OceanPixel and Lita Ocean Pte Ltd.

PLANNED DEPLOYMENTS

Renewable Energy Integration Demonstrator-Singapore (REIDS)

REIDS aims to power Pulau Semakau, an island south of mainland Singapore, which serves as a landfill, purely through renewables, including ocean energy. First of its kind in the region, the hybrid micro grid will facilitate the development and commercialization of energy technologies suited for tropical conditions that will help address the growing demand for renewable energy technologies in Asia. REIDS will integrate multiple renewables and novel technologies such as power-to-gas technologies and smart hybrid grids and enable the development of solutions suited for small islands, isolated villages, and emergency power supplies.

REIDS Onshore (renewable energy towards remote islandic conditions): The REIDS onshore project aims to solve engineering, economic, environmental and societal energy transition challenges for off grid communities. It customizes grid science towards remote islandic needs and integrates various renewables. Technologies deployed at the test bed include solar photovoltaic, wind, tidal, energy storage, bioenergy, innovative water desalination, hydrogen production, etc. Presently, work is in progress to make the island energy self-sufficient with its renewable sources.

REIDS Offshore (environmental impact assessment activity in Singapore): The offshore renewable energy integration and demonstration (Offshore REIDS) project, also termed as Tropical Marine Energy Centre (TMEC), has been initiated by ERI@N and financially funded by the ClassNK firm (a Japanese classification society) and seeks to pave the way for establishing the world's first scaled marine renewable energy testing facility for tropical needs. In March 2015, the feasibility study for the test sites was officially launched and is expected to be completed by December 2017. During this project, the resource mapping methodologies are well utilized to identify the ocean energy potential of the southern islands of Singapore that have been identified from the Maritime Port Authority of Singapore (MPA). Presently, an environmental impact assessment (EIA) for the test sites is being carried out to understand the

impact of ocean energy system deployment on marine life and environment. The EIA includes investigating the baseline conditions, possible effects of the test sites in the surroundings, and other associated research, such as underwater acoustics, water purity, sea level changes, tidal flow effects, etc. Geotechnical and geophysical surveys are also being planned. The outcome of this project will be extended towards Singapore's guidelines and standards development by working with Spring Singapore to support local supply chain's marine energy resource mapping guidelines of new regions, such as our neighbouring region of Southeast Asia and other tropical islands and remote coastal regions. Overall, the present project aims to develop technologies and a methodology for meeting energy needs towards the remote island region.

Deployment of Clean Energy Powered Water Generation System on Southern Islands of Singapore

Energy Research Institute @ Nanyang Technological University (ERI@N) with support from Singapore Government is planning to deploy clean energy powered water generation system and renewable systems on southern islands of Singapore in order to support the water and energy needs of southern islands which attract large number of tourists every year.

Floating Solar Deployment

- Singapore's Economic Development Board (EDB) has issued a request for information to explore the feasibility of a 100 MW floating solar project. The proposed facility will generate electricity for private sector consumption after construction. Such a facility will save 52,000 tonnes of carbon dioxide (CO₂) emissions per year.
- Sunseap Group, Southeast Asia's leading sustainable energy provider, is developing one of the world's largest offshore floating photovoltaic (OFPV) systems to be located north of Woodlands Waterfront Park, along the Straits of Johor. Supported by the Singapore Economic Development Board (EDB), the 5 MegaWatt-peak (MWp) floating solar system will generate about 6,388 MWh of renewable energy annually, once completed.

RELEVANT NATIONAL EVENTS

2nd and 3rd Workshops on Tidal Current Energy: Modelling, Verification and Validation

The main goal of this workshop is to prepare a **Tidal Energy Resource Modelling Guideline report** through the study of the various factors affecting the result of the simulations. This is likely to be a joint exercise effort concentrating on the accurate modelling and reporting of tidal energy resources.

As great multitude of tools and techniques are used to determine the amount of tidal resources and to quantify the resources available in different parts of the world, establishing a standard in extractable resource modelling can pave the way in promoting the adoption of tidal energy among the various stakeholders, as it can provide confidence in the amount of available resources. An **International Tidal Energy Working Group** is thus consequently formed and various research teams can conduct extractable resource studies to share their results and methodology, and work towards creating a standard report for modelling in harnessing tidal energy.

These workshops were organised and hosted by Energy Research Institute @ NTU (ERI@N), Singapore, through teleconferencing on 14th May 2018 and 9th November 2018.

Asian Conference on Energy, Power and Transportation Electrification (ACEPT) 2018

The Third Asian Conference on Energy, Power and Transportation Electrification (ACEPT) was organized by Energy Research Institute @ NTU (ERI@N), as a part of Asia Clean Energy Summit (ACES), and was held in conjunction with Singapore International Energy Week (SIEW 2018) in October 2018. ACEPT 2018 cooperated with the Institute of Electrical and Electronics Engineers (IEEE) to bring together the world leading experts to present emerging topics on energy, power, and transportation electrification.

International Floating Solar Symposium (IFSS)

International Floating Solar Symposium was organised by Solar Energy Research Institute of Singapore (SERIS) as a part of Asia Clean Energy Summit (ACES) and was held in conjunction with Singapore International Energy Week (SIEW 2018) in October 2018.



SPAIN

2018 has been a beneficial year for ocean energy in Spain. Several ongoing projects showed progress on reliability of ocean energy. Anyway, there are still several barriers to remove. Ocean energy needs to demonstrate the ability to improve on efficiency, reliability and feasibility to be considered as a potential contributor to the future energy mix supply.

OVERVIEW

2018 has been a beneficial year for ocean energy in Spain. Several ongoing projects showed progress on reliability of ocean energy (a new full year operation at Mutriku Wave Power Plant feeding electricity to the grid), marine operations and improvements under OPERA Projects, several developments on corrosion and fouling resistant coatings being tested at the Marine Corrosion Test Site “El Bocal”, a new offshore facility – HARSHLAB – placed at BIMEP to test materials, some off-grid wave buoy testing at PLOCAN and Punta Langosteira Test Site (a new test site at the Galician coast).

Anyway, there are still several barriers to remove. Ocean energy needs to demonstrate the ability to improve on efficiency, reliability and feasibility to be considered as a potential contributor to the future energy mix supply. And it needs a stable legal frame and proactive policy to push forward the development of the sector.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

During 2018, the Spanish Government started to work on the Energy and Climate National Integrated Plan 2021-2030, and the Energy Transition and Climate Change Law. Both, likely to be approved during 2019, will fix targets for 2030 and new rules to boost renewable energy in general and, hopefully, ocean energy specifically.

Nowadays, the energy policy relays on the new Ministry for the Ecological Transition and the main permits needed to develop an ocean energy power plant (environmental, use of the marine space, energy production) have to be approved by this Ministry.

The Basque Government approved in 2016 its Energy Strategy for 2030, which included a specific initiative to speed up technology and commercial development for marine energy and set a target of 60 MW by 2030.

Regarding the regulatory framework, no dedicated consenting process exists for ocean energy technologies in Spain but there are several legal documents affecting ocean energy projects:

- The Royal Decree 1028/2007 establishes the administrative procedure for processing applications for electricity generating facilities in territorial waters. Although it focuses on offshore wind, it also includes electricity generation from other marine renewable technologies;
- Law 2/2013, of 29 May, for protection and sustainable use of coastal and amending the previous Coastal Law of 1988. It provides the legal framework for occupation of the territorial sea, as well as governing issues affecting the fishing sector and safety conditions for maritime navigation;
- Law 21/2013, of 9 December, establishes a simplified process on Environmental Impact Assessment for all marine energy projects.

The Basque Energy Agency (EVE) launched a new call of its “Demonstration and validation of emerging marine renewable energy technologies” programme in 2018.

MARKET INCENTIVES

There are no specific market incentives for ocean energy in Spain but for renewable energy installations in general.

PUBLIC FUNDING PROGRAMMES

There are several national and regional funding programmes to support R&D and demonstration projects in Spain but most of them are not specific for ocean energy. The only two programmes focused on ocean energy are:

- OCEANERA-NET COFUND is an initiative of eight national and regional government agencies from six European countries, which has received funding from the European Union under the Horizon 2020 Programme for Research and Innovation. The participating countries/regions are: the Basque Country, Brittany, Ireland, Pays de la Loire, Portugal, Scotland, Spain and Sweden. The aim is to coordinate support for research and development in ocean energy, to encourage collaborative projects that tackle some of the key challenges identified for the sector as it progresses towards commercialisation. The project launched the first co-funded call during 2017 and approved projects started in 2018;
- The Basque Energy Agency (EVE) launched a new call of its “Demonstration and validation of emerging marine renewable energy technologies” programme in 2018. As previous calls, the programme has a budget of €2.5 million for a maximum of 3-year duration projects.

RESEARCH & DEVELOPMENT

OPERA project, funded under the H2020 programme and coordinated by TECNALIA, continues making good progress. 2018 saw the finalization of the bi-radial turbine tests at Mutriku Wave Power Plant and the implementation of that turbine in the MARMOK-A-5 device which was towed back to BiMEP site in October 2018. In addition, a sophisticated new type of mooring rope – elastomeric mooring tethers- was successfully deployed marking a significant new milestone for the project. More information on website: <http://opera-h2020.eu>

OCEANERA-NET funded projects with Basque participation:

- TECNALIA led a consortium with other partners from Spain (Zunibal, Ditrel and Basque Energy Cluster), Portugal (WavEC), Ireland (Smartbay) and UK (ORE Catapult). The so called RECODE project, which came to an end in December 2018, developed and tested cost-effective components specifically designed for reliable and sustainable delivery of ocean energy. These components comprise a safety monitoring and control device, a wave measurement buoy, an umbilical cable monitoring device and an underwater device-to-cable connector for a floating energy converter;
- IK4-Azterlan, IK4-Gaiker and Mikra Recubrimientos S.L. are working together with RISE Institutes Innventia, REPOL, WavEC, CorPower Ocean AB and Skandinavisk Ytförädling on the OCEANIC project focused on the development of corrosion and fouling resistant coatings for ocean energy structures, which are being tested at BiMEP open sea test facility.

2018 brought the launch of the second and third calls for trans-national access to European offshore renewable energy test facilities within the **MARINET2** project. This project, funded by the European Commission under the Research Infrastructure section of H2020, has the participation of 7 Spanish partners: BiMEP, CENER, CTC, EVE, IH Cantabria, PLOCAN and TECNALIA being the Marine Corrosion Test Site “El Bocal” of CTC one of the most required test facilities so far.

WESE is an EASME project that will collect and process environmental data from three wave energy devices installed in Spain and Portugal in order to improve the modeling capabilities, develop a licensing guide and facilitate the selection of possible locations for the implementation of this type of technology.

TRLplus is a Retos Colaboración project approved by the Spanish Ministry of Science, Innovation and Universities that aims to create innovative and highly competitive services to boost the offshore energy sector to the future market, supporting developers and side industry involved during the whole life cycle of an offshore farm.

NESSIE project searches innovative corrosion solutions and new materials in wave, tidal and offshore wind energy sectors through (i) technology roadmap and new materials (ii) supply chain analysis (iii) supporting consortia in scoping and developing demo, bankable projects. The Basque Energy Cluster and Fundación Asturiana de la Energía are working together with the Scottish Enterprise, ASTER – Società Consortile per Azioni, Sirris, Svenskt Marintekniskt Forum, The University of Edinburgh and Lombardy Energy Cleantech Cluster.

The **project ORPHEO** (2016-2018) awarded by the Spanish Ministry of Economy and Competitiveness to analyse the profitability of hybrid floating platforms to harness the wind and wave energy has continued with the activity approaching the objectives planned for 2018. This project consortium is composed by INGETEAM,

ENEROCEAN, University of Cadiz, University of Malaga and PLOCAN.

TECHNOLOGY DEMONSTRATION

PROJECTS IN THE WATER

BiMEP is an open sea test area located off the coast of Arminza, in the province of Bizkaia. Operating since June 2015, BiMEP offers technology developers an offshore area with suitable wave and wind resources, thereby enabling the demonstration and validation of the technical and economic viability of different concepts of energy converters, equipment and materials prior to commercial development.

BiMEP hosts the first floating wave energy device connected to the grid in Spain. The so called **MARMOK-A-5** device developed by OCEANTEC (acquired by **IDOM** in September 2018) was initially installed in 2016. After surviving two winters, the device was towed in for refitting and integration of the different innovations that have been developed in the OPERA project. In October 2018, the device was returned to its mooring site at BiMEP to collect more data for benchmarking.



MARMOK-A-5 device deployed by IDOM at BiMEP after refitting with OPERA innovations

Other test campaigns were carried out at BiMEP in 2018:

- the oceanographic buoy ANTEIA, developed by the company ZUNIBAL, has been tested at BiMEP obtaining very good results to collect, in real time, height, direction and period data, as well as the water temperature;
- IK4-AZTERLAN and TECNALIA also developed some material tests, the former under the OCEANIC project funded by OCEANERA-NET.

PLOCAN offers a test site for marine energy converters among other uses. It includes an offshore multipurpose platform providing workshops, laboratories, classrooms,

training rooms and open working areas around a test tank to facilitate sea trials and launching vehicle to the sea. The installation of two submarine cables (5 MW/13,2 kV) started in 2017 and was commissioned during 2018. They are expected to be grid connected in 2019. Some testing developed during 2018: TORGUER POWER (Norwich water pumping device).

Mutriku Wave Power Plant is the first multi-turbine wave energy facility in the world. It is integrated with the breakwater of Mutriku (Basque Country) and based on the OWC (Oscillating Water Column) principle. It has 16 air chambers and 16 sets of “Wells turbines + electrical generator” of 18.5 kW each. The plant was connected to the grid in July 2011, reaching a record of cumulative energy from waves powered to the grid of some 1.77 GWh. Two of the air chambers are prepared to test OWC components (air turbines, electrical generators, power converters and control systems). Until August 2018, the Portuguese company Kymaner continued testing its bi-radial air turbine. This novel turbine was completely designed and manufactured in Portugal, with a total investment value of circa €1 million, and represents the culmination of the development of a patent originated in IST- Instituto Superior Técnico, protected in several countries interested in wave energy. The turbine prototype has been specifically developed and tested under the EU project OPERA. Mutriku wave power plant has also adapted its premises to better host technology developers during their tests.

HarshLab is an advanced floating laboratory for the evaluation of standardized probes and components in an offshore environment developed by TECNALIA. It is suitable to test new materials and solutions against corrosion, ageing and fouling in real and monitored conditions. The first version of HarshLab was installed at BiMEP in September 2018. It can handle up to 125 samples in atmospheric zone, 320 in splash and 320 in immersion (765 probes in total). TECNALIA is working on a second version with more functionalities for testing components and subsystems applicable to offshore technologies, including ocean energy.



HarshLab deployed by TECNALIA at BiMEP during an inspection

WEP+, Ocean ERANET Cofund project, continuation of UNDIGEN and UNDIGEN+ Project, is a wave energy conversion demonstration project based on the industrial scale W1 (WEC by Wedge technology), accumulating roughly 4 years of testing at PLOCAN on the Canary Islands. The W1 system configures itself as an axisymmetric resonant point absorber with an innovative direct drive power take-off (linear generator).

Wedge Global, jointly with CTC and DEGIMA has also been developing SMARTWEC Project, aiming at optimizing wave energy converters point absorber type by increasing offshore reliability and energy output.

LifeDemoWave is a wave project developed in Galicia. Funded by the European Commission (LIFE+), the main objective of LifeDemoWave project is the demonstration of the feasibility of the use of wave power for electric generation in order to reduce greenhouse gas emissions. For demonstration purposes, a prototype of wave power generation and two different PTO to test, 25 kW each, have been developed and installed in the Galician coast (2 PTO to be sequentially tested in one hull). The prototype was deployed in June 2018 for a not grid connected test.

6 Spanish entities take part on this project: Quantum Innovative, Universidad de Vigo, CETMAR, Hercules Control, ACSM, and Grupo JOSMAR.

Galicia-based **Magallanes Renovables** has been tested its 2 MW floating platform for tidal energy at EMEC in Scotland to validate the technology, study O&M costs and approach the market.

BLUEGIFT is a project approved by Interreg Atlantic Arc which will implement a coordinated ocean energy technology demonstration programme that encourages

longer term demonstration and technology de-risking across the Atlantic Arc regions.

PLANNED DEPLOYMENTS

ARRECIFE plans to test its first AT-0 1:2 scale prototype at BiMEP during the summer of 2019. This test will serve to perform the first validation tests with a system without connecting to the grid. ARRECIFE technology is a floating system similar to a catamaran or trimaran that uses a series of turbines to transform wave energy. The system is designed to work optimally with wave heights of 1 to 5 m in height and is scalable and modular for different power capacities adding more rows of turbines or combining several modules. ARRECIFE also incorporates an immersion mechanism that is activated when the waves exceed 5 meters in height, ensuring the ability to survive during storms or adverse conditions of wind and sea.



ARRECIFE technology to be tested at BiMEP

Relevant events in 2018:

- The Wave Energy Basque Country group supported the organization of the Ocean Energy Europe 2018 conference in Edinburgh with a gold sponsorship.
- The Basque Country, through EVE – Basque Energy Agency - entered the SET-Plan Ocean Energy – Implementation Plan (IP) group. This Implementation Plan was adopted by the SET-Plan Steering Committee on 21 March 2018.
- In September 2018, IDOM CONSULTING, ENGINEERING, ARCHITECTURE, S.A.U. completed the takeover of OCEANTEC, including 100% of staff and key assets like the MARMOK-A-5 prototype deployed in BIMEP. IDOM has stated it will continue with the Oceantec's activities as well as its commitment to fulfil all the R&D projects formerly involving OCEANTEC.
- The Master in Renewable Energy in the Marine Environment (REM) is an Erasmus Mundus Joint Master Degree (EMJMD) offered by four universities: University of the Basque Country, University of Strathclyde, Norwegian University of Science and Technology and École Centrale de Nantes. These partner universities jointly engage in the overall execution and development of the Master. Each centre is responsible for the operation of the programme at its own institution. The Master is co-funded by the Erasmus+ Programme of the European Union.
- The Basque Government took over the presidency of the Marine Renewable Energy working group of the Atlantic Arc Commission in 2017. The creation of this group is the result of the growing interest for MRE in the Atlantic.
- EVE, TECNALIA and BEC (Bilbao Exhibition Centre) worked during 2018 with the Basque Energy Cluster on the organisation of the fourth edition of Marine Energy Week as part of a wider maritime event “World Maritime Week”, which will take place in Bilbao in February 2019.

SWEDEN

Key achievements in 2018 include the Swedish Energy Agency starting a new phase of its national ocean energy programme and several Swedish developers undertaking demonstration activities.

OVERVIEW

Key achievements in 2018 include the Swedish Energy Agency starting a new phase of its national ocean energy programme and several Swedish developers undertaking demonstration activities. Minesto installed and commissioned a 500 kW tidal device at Holyhead Deep off North Wales, while CorPower completed a half-scale demonstration of their wave energy device in EMEC, and initiated the next stage involving full scale devices.

SUPPORTING POLICIES FOR OCEAN ENERGY

In 2016, the Government together with several other political parties agreed on a long-term bipartisan energy policy for Sweden. The agreement includes a target of 100% renewable electricity production by 2040 and no net emissions of greenhouse gases in the atmosphere by 2045. Furthermore, a new Climate Act was introduced in 2018 which states that each government has an obligation to pursue a climate policy based on the climate goals adopted by the Riksdag.

Additionally, in 2015, the Ministry of Enterprises, Energy and Communications enacted a national maritime strategy¹, which identifies areas where action is needed to promote a sustainable development in the Swedish maritime sector. Ocean energy is one of many areas included. There is no national energy policy specifically for ocean energy.

MARKET INCENTIVES

The long-term Swedish energy policy relies on economic policy instruments, including a carbon tax, international emissions trading and a renewable electricity certificate system. All these instruments provide incentives for renewable energy and do not specifically target a particular renewable electricity conversion technology, i.e. they are technology neutral. There are no instruments in place to specifically incentivise ocean energy deployment.

PUBLIC FUNDING PROGRAMMES

Swedish governmental agencies support academic and private sector R&D at various stages of technology maturity. Funding providers include:

- The Swedish Energy Agency, www.energimyndigheten.se, is responsible for facilitating a sustainable energy system in Sweden. As such, the agency funds research, business and technology development and technology demonstration relevant to the sustainability of the energy system and the energy industry sectors.
- The Swedish Research Council, www.vr.se, which, among other things, is tasked to fund fundamental research and expensive equipment for research purposes within a number of topic areas.
- The Swedish Governmental Agency for Innovation Systems (VINNOVA), www.vinnova.se, supports business and technology development.

In addition, regional authorities may also grant funding.

¹ A summary in English can be found here: <http://www.government.se/contentassets/9e9c9007f0944165855630ab4f59de01/a-swedish-maritime-strategy--for-people-jobs-and-the-environment>

In 2018, a new phase of the Swedish Energy Agency's national ocean energy programme was started. The activities and priorities of the programme are guided by the Swedish Energy Agency's strategy for research and support to ocean energy which was finalised in 2017 and is available on the website². The programme will run from 2018-2024 and has a total budget of around €10,2 million. A first call for proposals has been held and decisions on which projects to fund are being finalised. The programme is intended to support research, experimental development and demonstration of technical solutions within the following focus areas:

- Improved knowledge regarding environmental impact during installation, operation and decommissioning;
- Improved reliability and durability;
- Development of systems, subsystems and components for cost-effective conversion of marine energy;
- Technical solutions for cost-effective electrical systems;
- Improved installation, operation and maintenance strategies.

The Swedish Energy Agency is also involved in OCEANERA-Net Cofund, which is a collaboration between national/regional funding organisations and EU to support the ocean energy sector and fund transnational projects. A second call for proposals was opened in January 2019.

RESEARCH & DEVELOPMENT

Swedish companies, universities and institutes were involved with several research and development projects during 2018. Below are just a few examples.

WECANet

WECANet is the first pan-European Network on an interdisciplinary marine wave energy approach, with networking tools and activities. It is EU funded and will last for four years. It will provide a platform and forum for efficient cross-border networking, exchange of information and identification of strategic research needed to deal with challenges and knowledge gaps for promoting deployment, commercialization and advancement of the wave energy sector. Uppsala University participates.

The Ocean Energy Scale-up Alliance (OESA)

OESA is a 3-year project funded by the Interreg North Sea Region Programme. The aim is to support the accelerated deployment of large-scale pilots from ocean energy technology companies in the North Sea Region. Uppsala University will contribute with expertise in wave and marine current energy areas.

UMACK

The UMACK project started in 2018 and will address ocean energy affordability, survivability, reliability and

installation through the demonstration of a generic anchor-foundation-mooring-connectivity system which aims to reduce capital and installation costs by up to 50%. The project is a collaboration between CorPower, Sustainable Marine Energy, TTI Marine Renewables, European Marine Energy Centre (EMEC) and Edinburgh University. The project has received support under the framework of the OCEANERA-NET COFUND project, with funding provided by the Swedish Energy Agency and Scottish Enterprise and co-funding by the European Union's Horizon 2020 research and innovation programme.

Direct drive generator development

The project seeks to demonstrate that direct drive systems for wave power can be as efficient as large hydropower generators (98%), also in partial load and speed, and can be in the same size and initial cost range as existing gear box solutions. In the project, a specialized linear transverse flux generator is being designed and built in the lab. The project takes place at KTH Royal Institute of Technology and has received funding from the Swedish Energy Agency.

R&D of dynamic low voltage cables between the buoy and floating hub in a marine energy system

The project is a collaboration between developers, research organisations and supplier, involving Chalmers department of Mechanics and Maritime Sciences, CorPower Ocean AB, Waves4Power, nkt Cables AB, Minesto and RISE Research Institutes of Sweden AB.

The project started in 2015 and ended in 2018, with funding from the Swedish Energy Agency.

The aim of the project was to develop a dynamic low voltage cable between buoy and floating hub. Tests were made in the laboratory and in the ocean at Runde. A mathematical model for power cables with fixings was developed to simulate the cable movements and to calculate the fatigue failure of the electrical conductor. New patent and knowledge derived from cables and accessories have been found.

TECHNOLOGY DEMONSTRATION

PROJECTS IN THE WATER

The deployments that have been made during 2018 have taken place outside Sweden.

CorPower Ocean develops a compact high-efficiency Wave Energy Converters, inspired by the pumping principles of the human heart. In 2018 CorPower completed Stage 3 demonstration in Orkney, EMEC Scapa flow site. After 18 months of combined dry and ocean testing of the C3 Wave Energy Converter (WEC), CorPower and project partners have taken important steps towards proving commercial viability of wave energy. By verifying

² <http://www.energimyndigheten.se/nyhetsarkiv/2017/energimyndigheten-antar-strategi-for-havsenergi/>

the ability to solve the two major challenges for wave energy, storm survivability combined with significant power production, a major demonstration milestone has been completed. This has been possible with the help of a novel storm protection mode, minimizing motion and loads, and a novel phase control technology called WaveSpring that amplify the motion and power capture performance in operational sea states.

The programme was financed by Wave Energy Scotland, InnoEnergy, Swedish Energy Agency and Interreg Foresea. CorPower is the first developer to complete Stage 3 demonstration within the Wave Energy Scotland programme.

Minesto develops a technology called Deep Green that can produce electricity from low-velocity tidal and ocean currents. In 2018 Minesto successfully installed and commissioned a 500 kW demonstrator at the company's site in the Holyhead Deep off North Wales. A significant milestone for the company, as it meant Minesto verified functionality and achieved electricity generation with a unit at a commercial scale of its unique subsea kite technology.

In parallel, prototype testing with a 3 kW scale model continued at Minesto's test site in Strangford Lough, Northern Ireland.

Waves4Power is a developer of a buoy-based wave energy converter system. They have been demonstrating their buoy in Runde, Norway. After completing an update of the WaveEL buoy, the system will once again be grid-connected to the local grid, tested and verified. In parallel there is continued development of a next generation buoy (WaveEL 4.0) using new materials and system optimization.

During 2017, the demonstration project at Sotenäs in Sweden was ended. **Seabased AB** has an ongoing dialogue with organizations to use Sotenäs demonstration site as a test site. Unfortunately, Seabased AB has recently advised that they will liquidate one of Seabased AB's wholly owned subsidiaries, Seabased Industry AB. This primarily affects the factory in Lysekil, which will be closed. Seabased AB intends to continue their manufacturing elsewhere.

PLANNED DEPLOYMENTS

Based on the results from the completed Stage 3 demonstration, **CorPower** started stage 4-5 programme in mid-2018 after securing the first phase of programme funding from the Swedish Energy Agency, InnoEnergy and equity investors. The activities are divided in the following two stages:

- Stage 4 – Demonstration and prototype certification of single device full scale C4 WEC, planned for 2018-2021.
- Stage 5 – Demonstration and type certification of pilot array with three C5 WECs, planned for 2021-2023.



CorPower C3 Wave Energy Converter in Orkney, Scotland.



Commissioning Minesto's kite

The HiWave-5 project aims at having at least three operational devices demonstrated in the pilot farm by 2023, delivering electricity to the grid with certification of availability and performance. Several potential sites along the European Atlantic coast have been reviewed for HiWave-5, with Billia Croo in Scotland and Aguçadoura in Portugal remaining as main candidates. Final decision is expected in 2019.

In 2019 **Minesto** plans to continue open sea demonstration with its 500 kW converter in the Holyhead Deep, Wales, with the purpose of demonstrating long-term testing and power production performance. Minesto also continues site development in Holyhead towards installation of more devices and going towards a commercial demonstration array with Minesto devices. Minesto plans to install the first of two tidal stream installations on the Faroe Islands in 2019. The company signed a collaboration agreement with local utility SEV in November 2018, for two grid-connected installations of Minesto's DG100 model as a first step of adding tidal energy by Minesto's technology to the Faroese Island's energy mix. Total installed capacity is approximately 200 kW.

UNITED KINGDOM

2018 saw extensive operating hours and generation from several bottom-fixed and floating tidal devices with multi-GWhs of generation being clocked up. Wave energy technology has progressed with a number of large-scale laboratory and offshore tests having been undertaken to validate innovative concepts.

OVERVIEW

2018 saw extensive operating hours and generation from several bottom-fixed and floating tidal devices with multi-GWhs of generation being clocked up. Wave energy technology has progressed with a number of large-scale laboratory and offshore tests having been undertaken to validate innovative concepts. This activity has been supported by a set of positive Research and Development (R&D) and industrial policies, however a dedicated revenue support for ocean energy is required to establish a route to market. This issue is being investigated by the new Marine Energy Council, formed in 2018, intended to be the unified voice of the sector to engage with Government and other stakeholders to secure support. This is being supported by the ORE Catapult's 'Tidal stream and wave energy cost reduction and industrial benefit' 2018 report, which highlights the significant potential economic and employment benefits from ocean energy to the UK.

Wave

Wave Energy Scotland (WES) continues to be the focus for wave energy R&D activity in the UK in terms of funding provision for wave energy innovation and demonstration. The technology sub-system R&D streams are now maturing with the best of these to be integrated and tested at the European Marine Energy Centre (EMEC) with two part-scale wave energy devices planned for 2020 deployment. Marine Power Systems, CorPower and Wello Oy successfully deployed and tested their devices in UK waters during 2018.

Tidal Stream

Tidal stream projects made significant strides in demonstrating performance and reliability. SIMEC Atlantis' (formerly Atlantis) four-turbine 6 MW MeyGen project has now clocked up over 10 GWh of generation with maintainability also demonstrated through recovery and reinstallation operations. The Nova Innovation three-turbine 0.3 MW array has continued to operate and with the integration of a Tesla battery system, it is now able to provide continuous power to the local grid. Orbital Marine Power (formerly Scotrenewables) enjoyed a long production run of the floating SR2000 2 MW device, achieving 3 GWh of generation. All have continued working on technology improvements and planning project expansions.

Tidal Range

The 2017 UK Government strategic review of tidal lagoons established that the 320 MW Swansea Bay tidal lagoon would serve as a "pathfinder" project for the sector subject to value for money for the UK taxpayer. The project was seeking a 35-year power price contract plus significant investment by the Welsh Government. In 2018, the UK Government concluded that this represented poor value for money, the costs believed to be much higher than alternative sources of low carbon power, so would not agree these terms. The project developer is seeking alternative funding models that can address this.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The UK Government's department for Business, Energy and Industrial Strategy (BEIS) retains overall responsibility for energy policy in the UK although powers related to planning, fisheries and the promotion of energy efficiency have been devolved to the governments of Scotland, Wales and Northern Ireland.

Flagship strategic policies of BEIS are having the greatest direct impact on the development of marine energy within the UK. The 2017 UK Government's Clean Growth Strategy states that ocean energy technologies *"could also have a role in the long term decarbonisation of the UK, but they will need to demonstrate how they can compete with other forms of generation."* A progress update for this strategy was published in October 2018 and makes reference to the sector deal made with offshore wind and additional funding granted to the ORE Catapult.

The UK Government's Industrial Strategy supports the development of the energy sector with 'clean growth' one of the four 'Grand Challenge' themes underpinning the strategy. The key revenue support system for renewables, including marine energy, is the contracts for difference (CfDs) – also the responsibility of BEIS.

To date, the UK has invested an estimated £508m of private funds into the development of ocean energy technology. This has been supported by £70m of direct public support to technology developers, part of £300m of wider public support (including academia and test centres). To inform budget setting for 2019 onwards the UK Government has convened the Energy Innovation Needs Assessment (EINA) process. This coordination activity will bring together UK Government funding agencies from across the UK to prioritise and allocate R&D investment between the low-carbon technologies, including ocean energy.

UK organisations continue to benefit extensively from European R&D funding with the UK ocean energy sector receiving over €60m from the FP7 and Horizon 2020 programmes, a figure four times higher than the next recipient nation.

Scotland

The Scottish Energy Strategy defines the ambitions for the sector through to 2050 also taking a whole-systems approach to the progression towards the equivalent of 50% of heat, transport and electricity consumption sourced from renewable sources. This will enable delivery of Scotland's flagship Climate Change (Scotland) Act 2009 to reduce Scotland's greenhouse gas emissions by 80% by 2050. Wave and tidal projects account for 0.02 GW of the total 21.3 GW renewable capacity in Scotland.

Marine Scotland is the Directorate of the Scottish Government responsible for the management and use of Scottish seas, including planning and licencing of marine energy projects. This is administered within the scope of a 2015 National Marine Plan, intended to ensure sustainable use of Scotland's seas and the resources therein. A 2018 refresh of the Plan focussed mainly on enabling offshore wind development.

The Scottish Government continues to support the ocean energy sector including ongoing funding of Wave Energy Scotland. Through targeted innovation projects and research activities, several new funding awards were made in 2018.

In April 2018, Crown Estate Scotland passed its one-year operative milestone since the Crown Estate's management duties in Scotland were transferred to the Scottish Government. Managing seabed rights for renewable energy interests from the foreshore to 200 nautical miles (nm), Crown Estate Scotland has an important role to play in enabling marine energy. Applications for ocean energy projects of up to 30 MW are accepted at any time.

Wales

'Energy Wales' was published by the Welsh Government in 2012, and outlines how the Welsh Government intends to grow Wales' economy in the long term through energy job creation and community benefit from energy infrastructure projects. The Welsh Government has a 70% renewable electricity mix contribution target by 2030, a proportion of which will come from marine sources. To achieve this, the Welsh Government has allocated £100m of EU structural funding to the Welsh European Funding Office Marine Energy Fund.

Delivery of this ambition is being coordinated by Marine Energy Wales, a public organisation, which guides a cluster of technology developers, research institutions, supply chain and the public sector bodies. Its primary objectives are the creation of a successful ocean energy industry in Wales through guidance, collaboration facilitation and public promotional activity. Infrastructure under development includes two wave and tidal stream Demonstration Zones and other test facilities including the Marine Energy Test Area, Morlais Tidal Demonstration Zone and Pembroke Dock Marine. Skills and innovation are being supported by the Marine Centre Wales, which opened in 2018 with £2.8m funding, and the Marine Energy Engineering Centre of Excellence.

Northern Ireland

Northern Ireland's energy strategy lies within the Department for the Economy (DfE). The DfE has published a vision to 2050 in their Sustainable Energy Action Plan 2012. Related to this, the Strategic Energy Framework 2010-2020 describes a vision of a Northern Ireland powered by affordable, sustainable and low-carbon renewable electricity. Within this Framework sits the Offshore Renewable Energy Strategic Plan (ORESAP) 2012-2020, which also applies to ocean energy.

In 2018, Northern Ireland has progressed the development of a Marine Plan, which aims to maintain a 'healthy marine area which is managed sustainably for the economic, environmental and social prosperity of present and future generations'. The Marine Renewables Industry Association (MRIA) supports the development of technology in wave, tidal, floating wind and hybrid generation across both Northern Ireland and the Republic of Ireland. In late 2018, MRIA published the 'Discussion Paper on the Marine Spatial Planning Needs of the Marine Renewables Emerging Technologies' to support the development of the Marine Plan.

Regional development agency InvestNI continues to support the sector with a particular focus on finding matches between the sector and the Northern Irish supply chain.

MARKET INCENTIVES

Contracts for Difference (CfDs)

The UK Government continues to offer revenue support to a variety of renewable energy technologies through the Contract for Difference (CfD) programme. Based on top-up payments to a strike price, CfDs offer long-term

price stabilisation and are awarded via competitive auctions. The Clean Growth Strategy and Budget has confirmed that the £557m remaining in the former Levy Control Framework (LCF) will be allocated to further CfD auctions to 2020, with the next auction planned for early May 2019.

Ocean energy technologies are within the "less established" technologies category as part of the CfD auctions, which also includes offshore wind and advanced conversion technologies. Ocean energy technologies have yet to gain a CfD through the competitive auction process. There was no CfD auction in 2018. The third round of auctions, worth £60m, will open in May 2019. Draft strike prices of £281/MWh for wave and £225/MWh for tidal stream were quoted for projects due to deploy in 2023/24 in the BEIS 2017 Draft Allocation Framework. These are shown in the table below, compared with the 2019 draft strike prices for other generation technologies in the "less established" category and the 2017 CfD second round of auction results. Despite defining strike prices for wave and tidal, without a ring-fenced budget for these technologies it is not expected that they can gain a CfD in a competitive auction.

UK Contracts for Difference for less established technologies: Draft strike prices and Auction results (£/MWh)

Technology	Draft strike prices		2017 Auction results	
	2023/24	2024/25	2021/22	2022/23
Offshore wind	56	53	74.75	57.50
Advanced conversion technologies (with or without CHP)	113	111	74.75	40
Anaerobic digestion (with or without CHP, >5MW)	122	121	-	-
Dedicated biomass with CHP	121	121	74.75	-
Wave	281	268	-	-
Tidal stream	225	217	-	-
Geothermal	129	127	-	-

PUBLIC FUNDING PROGRAMMES

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 £6 billion budget funded primarily through the Science Budget by Business, Energy and Industrial Strategy (BEIS). The research councils and

bodies operating within UKRI are the Engineering and Physical Sciences Research Council (EPSRC), Innovate UK, 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), Research England, and the Science and Technology Facilities Council (STFC).

Innovate UK

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, other sectors, policymakers and future customers on a domestic and international scale. Innovate UK is also a member of UKRI.

Wave Energy Scotland

WES – fully funded by the Scottish Government – is taking an innovative and unique approach to the development of wave technology in a research programmes. WES funds the progression of innovative technology to commercialisation through stage-gate funding. Three levels of calls fund projects through initial to prototype testing stages. Funding is allocated within four categories of technological requirements, concerning internal components, overall WEC design, materials and manufacturing.

RESEARCH & DEVELOPMENT

This section contains an overview of the primary research institutions and their core project activity in 2018.

KEY R&D INSTITUTIONS

Supergen

Set up in 2001, the wave and tidal Hub of Supergen - Sustainable Power GENERation and supply - Programme delivers sustained and coordinated research into the development of the ocean energy sector. Supported by EPSRC through calls and Centres for Doctoral Training, the programme has resulted in greater collaboration between academia, government and industry, the creation of new strategies and innovation programmes and provided an opportunity for international collaboration.

Supergen UKCMER

Running from 2003 until 2018, the Supergen UK Centre for Marine Energy Research (UKCMER) sought to engage developers, industry, academia and other stakeholders to conduct fundamental and applied research that accelerates deployment of ocean renewable energy. Supergen UKCMER culminated in this capacity in December 2018 after 15 years of operation. The Centre held an assembly in Edinburgh to close down the long-running project and to introduce its successor, the Supergen Offshore Renewable Energy (ORE) Hub. Supergen UKCMER was funded by the EPSRC and coordinated by the University of Edinburgh.

Supergen ORE Hub

The Supergen ORE Hub is coordinated by the University of Plymouth and now consolidates offshore wind research activity with that of wave and tidal. The Hub launches in early 2019, and will bring together research institutions

across the UK to align activity, progress the sector to ambitious levels and cultivate a ‘research landscape’ – a justified and collaborative interactive map of sector needs from a technological, funding and ecological perspective that will be available for public consumption.

The Offshore Renewable Energy Catapult (ORE Catapult)

ORE Catapult is the UK’s flagship technology and innovation research centre, combining excellent research, development, demonstration and testing facilities with leadership, industrial reach and engineering expertise. ORE Catapult accelerates the design, deployment and commercialization of renewable energy technology innovation. ORE Catapult owns and operates over £250m of test and validation facilities including a 7 MW offshore wind turbine, a 100m blade test facility, a 1.5MW drivetrain test facility, subsea docks and HV electrical labs. By the end of financial year 2017/2018, ORE Catapult had supported 410 SMEs, participated in 196 R&D projects, and engaged in 301 academic collaborations and 628 industry collaborations.

R&D PROJECTS

This section outlines a selection of projects carrying out R&D activities in the UK in 2018. The projects presented do not form an exhaustive list but an overview of the UK’s contribution to the progression of the sector.

EnFAIT

The Enabling Future Arrays in Tidal (EnFAIT) project is a €20.2m Horizon 2020 project, which began in July 2017 and will run until June 2022. The project is a partnership of nine European companies and academic partners, led by Scottish tidal energy developer Nova Innovation. EnFAIT builds on Nova’s existing operational tidal array in the Bluemull Sound, in Scotland’s Shetland Islands, which was the world’s first grid connected offshore array of tidal energy turbines. It will extend the Bluemull Sound array from three to six turbines and demonstrate that high array reliability and availability can be achieved using best practice maintenance regimes. In 2018, the project successfully completed the design and planning phase and moved into the delivery phase, which will see three new turbines built and deployed at the site.

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

NeSSIE

The North Sea Solutions for Innovation in Corrosion for Energy (NeSSIE) project is an EU funded research project primarily focused on the research and translation of cross-industry anti-corrosion technologies in the North Sea basin (NSB) to the offshore renewable energy sectors. Led by Scottish Enterprise, NeSSIE is composed of eight partners over five countries. Planned to conclude in April 2019, the two-year project has produced a Roadmap for anti-corrosion solutions in the Offshore Renewable Energy sector and selected three demonstration projects to move the sector forward.

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

TiPA

The Tidal Turbine Power Take-Off Accelerator (TiPA) project focuses on the testing of an innovative Direct Drive Power Take-off (PTO) solution for tidal turbines, with the aim of reducing the lifetime cost of tidal power by 20%. Running until late 2019, TiPA is led by Nova Innovation and funded by EU Horizon 2020. The project includes accelerated onshore and in-sea testing of a prototype PTO with third party validation and a commercialisation strategy for selling and licensing the product to ocean energy technology developers and related industries. Now into its final year, the TiPA project is progressing well. The PTO successfully completed the accelerated onshore testing phase at RWTH Aachen University during summer 2018 and will complete the in-sea testing phase in spring 2019. The project consortium is comprised of six academic and industrial European partners.

<http://www.tipa-h2020.eu/>

Wave Energy Scotland

In 2018, WES continued strong progress through its stage gate research, development and innovation programme. In 2018, Wave Energy Scotland (WES) awarded a total of £12.5m to thirteen wave energy research and development projects as the programme continued towards integration of sub-systems and deployment of fully functional prototype wave energy converter in Scottish seas. One project received £2.5m to pass into the final stage of the Power Take Off programme. This joined three ongoing Stage 3 projects and one completed project, which brought the programme's first in-sea technology testing. Three projects were funded a total of £632k to continue development of control systems and three projects were awarded £1.4m to progress engineering of structural materials for wave energy converters. The turn of 2019 delivered a key milestone for WES, the award of £7.7m to two Novel Wave Energy Converter companies to build fully functional pilot devices for testing in Scottish seas in 2020. Funding allocated by EMEC in 2018 went toward the following: £7.7m for two half-scale wave energy converter devices; £2.5m for power take-off development; £526k to 3 Controls projects; £1.4m to 3 Materials projects; and £320k for research landscaping. This brings overall investment to £38m in 86 projects since 2015. To date WES has funded 86 contracts and been involved with 177 separate organisations, across 13 different countries.

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

FORESEA

The FORESEA (Funding Ocean Renewable Energy through Strategic European Action) project grants free access to a network of northwestern European tank test centres to ocean energy technologies. These test centres are EMEC in Orkney, SmartBay in Ireland, SEM-REV in France and Dutch Marine Energy Centre in the Netherlands. FORESEA receives €6.45m in European funding, of a total €10.75m budget. The project funded a number of innovative technologies and initiatives in 2018; specifically CorPower Ocean, Orbital Marine Power, Naval Group and Whitford. FORESEA will run a fifth real-sea testing call in

early 2019. In addition to this, FORESEA gave rise to Blue-GIFT, a coordinated energy technology demonstration programme led by EMEC and focused around the Atlantic Arc. Blue-GIFT was launched in October 2018.

<http://www.nweurope.eu/projects/project-search/funding-ocean-renewable-energy-through-strategic-european-action/>

CLEMATIS

The CLEMATIS (Cable Lifetime Enhancement via Monitoring using Advanced Thermal and electrical Infrastructure Sensing) project, funded by Innovate UK, finished successfully in summer 2018. CLEMATIS achieved its objective of developing a smart integrated monitoring system for offshore underwater electricity cables. The project grew from the ORCHIDS feasibility study, progressing the system from desk-based theoretical testing, through to on- and offshore field tests. Project partners were led by Fraunhofer UK Research.

<http://www.emec.org.uk/integrated-subsea-cable-monitoring-system-tested-at-emec/>

TECHNOLOGY DEMONSTRATION

PROJECTS IN THE WATER

Test Centres and Demonstration Zones

Critical to enabling deployment of wave and tidal devices, especially those under R&D, is the provision of offshore test centres and demonstration zones. Several of those have seen devices being deployed and tested in 2018 whilst others are an earlier stage of development. A selection of these facilities is described below.

The European Marine Energy Centre (EMEC)

EMEC is a UKAS accredited test and research centre focusing on wave and tidal power development. Based in Orkney, an archipelago in the north of Scotland, EMEC has thirteen open-sea grid-connected test berths and two scaled test sites. Established in 2003, the centre provides a wide variety of test conditions, with a depth range of 1 to 51 metres and significant wave height average of two to three metres. A diverse environment allows testing in a multitude of seabed and shoreline contexts, and water-depths.

Wave Hub

Wave Hub is a pre-installed grid connected site approximately 10 nautical miles (16 km) off the north coast of Cornwall for the testing of large-scale offshore renewable energy devices. The site has a Section 36 electricity consent and holds a 25-year lease for eight square kilometres of seabed divided into four separate berths. Wave Hub is owned by BEIS and operated by Wave Hub Limited.

FaBTest

FaBTest is a 2.8 km² test site at Falmouth Bay in Cornwall. The relatively sheltered location of the bay allows for smaller and concept devices and components to be tested. The pre-consented site, leased from the Crown

Estate, has a six-metre tide range and six- to nine-metre significant wave height variance.

Marine Energy Test Area (META)

Marine Energy Wales are establishing a new test area in the Milford Haven Waterway in Pembrokeshire. The Area will comprise of a variety of sites with consent and grid connection, which will facilitate testing at component, sub-assembly and single-device stages. Development of the site will be informed by strategic advice provided by established test-centres EMEC and Wave Hub.

Morlais Tidal Demonstration Zone

The site in West Anglesey was primarily for its tidal resource and access to local infrastructure. Areas within the 37 km² site are being sub-let for test and demonstration activities alongside some of the first array scale commercial projects. This is a £33 million project, which has recently been awarded £4.5m of EU and Welsh Government funds. Developers planning projects there include Orbital Marine Power.

DEMONSTRATION PROJECTS

This section is a non-exhaustive list of key projects tested, installed in the sea and operating in 2018.

MeyGen

The MeyGen array is owned and operated by SIMEC Atlantis Energy in Scotland's Pentland Firth. In December 2018, the MeyGen project confirmed it has surpassed 10 GWh of generation onto the grid since project commencement. Around this time, the remaining two, of four, turbines were successfully redeployed following modification work in winter 2018.



MeyGen deployment (Source: SIMEC Atlantis Energy)

Nova Innovation

Nova Innovation was granted an extension to their existing seabed lease by Crown Estate Scotland, significantly increasing capacity from 500 kW to 2 MW. This extension will enable Nova to progress their EnFAIT project with the installation of three additional Nova M100 turbines, each rated at 100 kW. This installation will double the generating capacity deployed at the site

and increase the number of turbines in the water from three to six. In October 2018, Nova Innovation installed a Tesla battery in the Shetland Tidal Array to create the world's first baseload tidal power plant, capable of providing predictable, controllable and renewable power to the grid.



Nova Innovation Deployment, Bluemull Sound (Source: Nova Innovation)

CorPower

CorPower deployed their half-scale C3 device and demonstrated 18 months of combined dry and ocean testing, completing the Stage 3 demonstration programme mid-year at EMEC Scapa Flow scale test site. EMEC oversaw testing in dry and wet conditions and provided verified quality control and assurance services at each stage. In partnership with EMEC, CorPower will feed the results from these tests into their WaveBoost project, improving their upcoming technology developments.



CorPower Ocean C3 deployment at EMEC (Source: CorPowerOcean)

Marine Power Systems

Swansea-based wave developer Marine Power Systems (MPS) built their 10 kW WaveSub device in Pembroke Dock and are currently finalising tests in FaBTest, Cornwall. This was a £5.5 million project, which has received £3.5 million WEFO & Welsh Government funding. More recently, MPS are underway on the next phase of the WaveSub development, which will also be built in Pembrokeshire.

Orbital Marine Power

Tidal developer Orbital Marine Power continued testing of their first full commercial scale machine, the SR1-2000 2 MW twin rotor floating tidal turbine at the site. In 12 months of continuous operation, the machine supplied 3 GWh - at times over 25% of the electricity demand of the Orkney Islands.



Orbital Marine Power's SR1-2000 device (Source: Orbital Marine Power)

Minesto

In 2018 Swedish tidal developer Minesto built and deployed their commercial scale DeepGreen500 tidal kite off Holyhead, North Wales. This project was supported by €13 million of European Regional Development Fund through the Welsh Government. Testing of the DG500 will continue in 2019.



Minesto DG500 being deployed at Holyhead Deep, Wales (Source: Minesto)

Wello Oy

At EMEC's Billia Croo test site, Wello Oy's Penguin WEC marked its first year of deployment in March 2018 and continues to demonstrate survivability in weathering a number of storms and waves of over 18 metres.



Wello Oy Penguin operating at EMEC Billia Croo test site (Source: EMEC)

PLANNED DEPLOYMENTS

This section contains a non-exhaustive summary of wave and tidal projects expected to be deployed in 2019 and early 2020.

Wave

Bombora Wavepower: Australian wave energy developer Bombora Wavepower set up their EU headquarters in Pembroke Dock, Wales at the end of 2017 and is now conducting a £20 million project to construct and test a 1.5 MW wave device off the coast of Pembrokeshire. Bombora secured a £10.3 million ERDF grant to support this project and now have a team of 18 staff based at Pembroke Dock.

Laminaria: Laminaria's 200 kW LAMWEC wave device will be deployed at EMEC's Billia Croo site in 2019. The surge point-absorber device's design includes a bespoke storm protection system, which will maximise survivability and optimise operability in all weathers. This has benefitted from MaRINET2 and FORESEA funding for test site access.

Wello Penguin: Wello's next generation Penguin WEC was deployed in Tallinn, Estonia throughout 2018 and will be relocated to EMEC for deployment next to the existing Penguin WEC in 2019. In November, a marine licence was granted for the installation, operation and decommissioning of the three-WEC array and the subsea hub at EMEC. Ultimately a three-device farm will be tested at EMEC.

Tidal

Instream Energy Systems: Manufactured and constructed by Leask Marine, Instream Energy Systems will deploy their surface floating tidal platform at EMEC in 2019. The 100 kW device will be the first tidal platform to be constructed at EMEC. The project is funded by Innovate UK's Industrial Strategy Challenge Fund.

Magallanes Renovables: Magallanes Renovables have completed construction of their 2 MW floating tidal device and during 2018 it was located to Orkney. Final commissioning and installation will take place during 2019 at EMEC's Fall of Warness test site.

Nova Innovation: Nova Innovation plan to install three more M100 100 kW turbines alongside the three turbines currently in place at Bluemull Sound in Shetland. The first will be deployed in 2019 with the remaining two planned for installation in 2020, for extended operation and to understand array interactions across the six-turbine array.

Orbital Marine Power: In 2019 Orbital Marine Power will design and build their optimised production model, the Orbital O2 2 MW, for deployment at EMEC in 2020. The Orbital O2 is funded under Horizon 2020 FloTEC (Floating Tidal Energy Commercialisation), with funding from Interreg North-West Europe ITEG (Integrating Tidal Energy into the European Grid) for the moorings and actuation system. Orbital Marine Power also received £7 million of peer-to-peer Abundance investment in October 2018 to build the production model.

SIMEC Atlantis Energy: Project Stroma/Phase 1B of SIMEC Atlantis Energy's MeyGen project is to install an additional two Atlantis turbines uprated to 2MW each using larger diameter rotors and more powerful generators. Deployment is planned for late 2019 at the earliest subject to consents and funding with €16.8 million revenue support package already secured under the European Commission's NER300 programme. Project Stroma will lead into further phases of expansion up to about 400 MW of generation.

Tocado: As part of the Horizon 2020 funded InToTidal project Tocardo's Universal Foundation System (UFS) floating tidal platform is planned to be deployed for testing at EMEC in 2019. The platform is capable of integrating five-turbines. While testing of the platform will initially use Tocardo's turbines, the platform is intended to provide a generic solution viable for any turbine model.

RELEVANT NATIONAL EVENTS

27th February 2018 and 18th July 2018 – Marine Energy Policy Fora, London

28th February 2018 – RenewableUK Wave and Tidal 2018, Glasgow

19th April 2018 – Marine Energy Wales Annual Conference 2018, Cardiff

2nd – 3rd May 2018 – AllEnergy 2018

2nd May 2018 – Marine Energy Council (MEC) kick-off meeting, Glasgow

18th July 2018 – Marine Energy Showcase, London

26th September 2018 – Scottish Renewables Marine Conference 2018, Edinburgh

30th – 31st October 2018 – Ocean Energy Europe 2018, Edinburgh

5th December 2018 – Supergen Annual Assembly, Edinburgh

6th December 2018 – Wave Energy Scotland Annual Assembly, Edinburgh

Marine Energy Council

In 2018, the industry formed the Marine Energy Council as to engage with the UK Government and other stakeholders in a unified manner. The council is made up of representatives from the industry including those from Renewable UK, Scottish Renewables, Marine Energy Wales and the Offshore Renewable Energy Catapult, plus members from technology and project developers, supply chain companies and consultants. Throughout the year, the industry has engaged with a number of parties to develop a suitable benefit case for the support by the UK Government of marine energy through new revenue support models aligned with its industrial strategy, bringing investment, export opportunities and jobs to the coastal communities where the sources of marine energy can be accessed.



USA

The U.S. Department of Energy's (DOE's) Water Power Technologies Office (WPTO) aligns itself with the goals outlined in the SOST Decadal Vision, but more generally serves to advance cutting-edge technology to modernize the U.S. hydropower fleet and drive leadership in new ocean and river energy, with the goal of delivering low-cost power and resiliency to the nation's power grids. WPTO and a handful of other agencies, including the National Science Foundation and the U.S. Navy's Office of Naval Research, are the primary groups assisting with funding for research of ocean energy technologies.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The National Science and Technology Policy, Organization, and Priorities Act of 1976 established the Office of Science and Technology Policy (OSTP) to provide the President and others within the Executive Office of the President with advice on the scientific, engineering, and technological aspects of the economy, national security, homeland security, health, foreign relations, the environment, and the technological recovery and use of resources, among other topics. OSTP leads interagency science and technology policy coordination efforts, assists the Office of Management and Budget with an annual review and analysis of Federal research and development in budgets, and serves as a source of scientific and technological analysis and judgment for the President with respect to major policies, plans, and programs of the Federal Government.

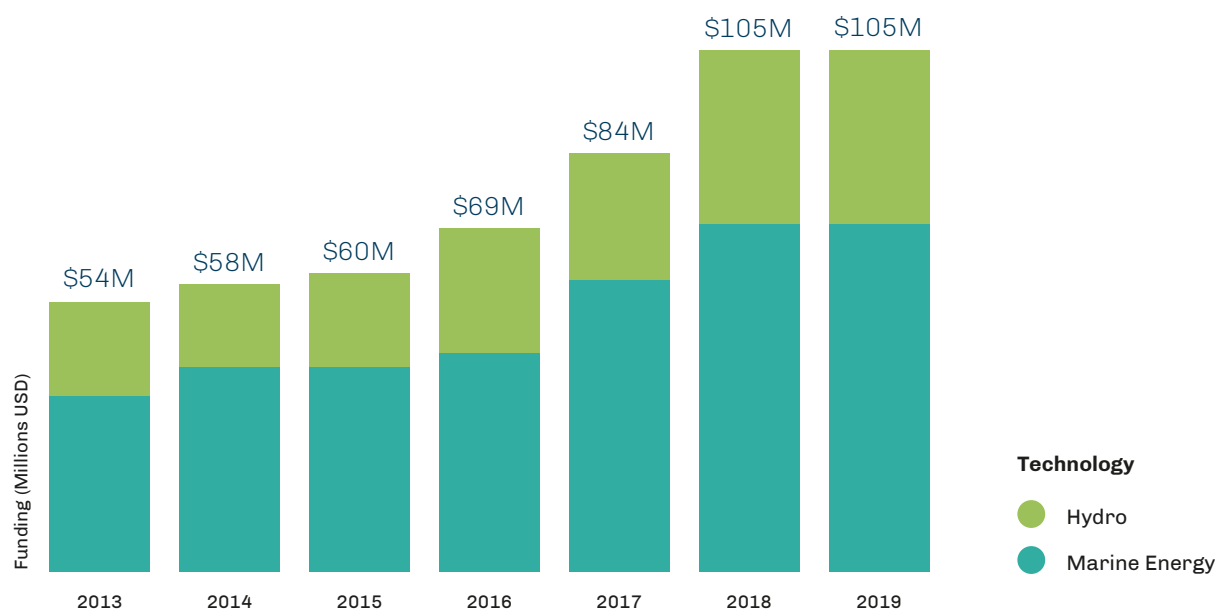
Within the OSTP exists the Subcommittee on Ocean Science and Technology (SOST), whose purpose is to advise and assist on national issues of ocean science and technology. In November 2018, the SOST released the second iteration of a decadal report titled *Science and Technology for America's Oceans: A Decadal Vision*. The SOST advises and assists on national issues of ocean science and technology, and the report identifies five goals to advance U.S. interests in the coming decade, including promoting new energy sources and developing resilient coastal communities. This document provides guidance to many agencies working on ocean science and technology, including ocean energy, and helps them coordinate efforts.

The U.S. Department of Energy's (DOE's) **Water Power Technologies Office (WPTO)** aligns itself with the goals outlined in the SOST Decadal Vision, but more generally serves to advance cutting-edge technology to modernize the U.S. hydropower fleet and drive leadership in new ocean and river energy, with the goal of delivering low-cost power and resiliency to the nation's power grids. WPTO and a handful of other agencies, including the National Science Foundation and the U.S. Navy's Office of Naval Research, are the primary groups assisting with funding for research of ocean energy technologies.

Because marine renewable energy is an early stage market with limited incentives for investment, WPTO has a clear role in expediting the development of innovative marine renewable energy technologies. WPTO makes investments that support key technology innovations, mitigate risks, and assist the private sector in creating a robust U.S. marine renewable industry by providing funding and technical assistance. The Office has been working to solicit comments and refine a publicly available long-term strategy for its research and development (R&D) priorities (<https://www.energy.gov/eere/water/articles/wpto-releases-updated-draft-mhk-strategy>).

WPTO funds research in four main topic areas: (1) foundational and crosscutting R&D, (2) technology-specific system design and validation, (3) reducing barriers to testing, and (4) data sharing and analysis. Work in each topic area provides the industry with fundamental tools, research, and innovations that tackle specific challenges hindering development.

Federal funding for WPTO has maintained an upward trend since fiscal year (FY) 2013. WPTO's FY 2018 and 2019 annual budgets were each funded at \$105 million—a 25% increase from FY 2017 and its highest level ever. More information on WPTO can be found at: water.energy.gov



U.S. Department of the Navy

The Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC) continues to actively support R&D of various renewable energy conversion technologies. NAVFAC EXWC's funding efforts focus on advancing technology development to harness marine energy resources to ensure energy security and for powering U.S. Navy and Marine Corps assets both on- and off-shore. NAVFAC is funding and actively managing the Navy's Wave Energy Test Site (WETS) in Hawaii, including the University of Hawaii's Hawaii Natural Energy Institute's on-site monitoring and support of the test site, and marine renewable energy development efforts at the University of Washington, Applied Physics Laboratory.

In FY 2018, the Defense appropriations bill passed by Congress provided \$35 million for the U.S. Navy to support Alternative and Renewable Energy research and development. The FY 2019 Defense Appropriations bill saw a \$7 million increase specifically for marine and hydrokinetic (MHK) energy research. Separately, the FY 2019 National Defense Authorization Act included \$20 million for the Navy to conduct research on maritime robotics technology, which could also support marine energy.

NATIONAL LEGISLATION

In October 2018, the **Water Resources Development Act of 2018**, included as title I of the America's Water Infrastructure Act of 2018 (S. 3021), was signed into law.

The new law provides investment in ports, channels, locks, dams, and other infrastructure that supports the maritime and waterways transportation system and provides flood protection for homes and businesses. This represents Congress' continued interest in locally driven, but nationally important, federal investments in water resources infrastructure.

In June 2018, President Trump signed **Executive Order 13840 Regarding the Ocean Policy to Advance the Economic, Security, and Environmental Interests of the United States**. This Executive Order replaces the previous one from 2010 and places an emphasis on economic growth and national security, as well as establishing a new federal interagency Ocean Policy Committee.

MARKET INCENTIVES

A market incentive for marine renewable energy developers are **Clean Renewable Energy Bonds (CREBs)**. CREBs are tax credit bonds, the proceeds of which are used for capital expenditures incurred by governmental bodies (including states and municipalities), public power providers, or cooperative electric companies for a qualified renewable energy facility, marine renewables included. The bondholder receives federal tax credits in lieu of a portion of the traditional bond interest, resulting in a lower effective interest rate for the borrower. The issuer remains responsible for repaying the principal on the bond.

At the state level, **Qualified Energy Conservation Bonds (QECBs)** are another incentive program that may be used by state, local, and tribal governments to finance certain types of energy projects. QECBs are similar to CREBS, but are not subject to a U.S. Department of Treasury application and approval process. With QECBs, the borrower who issues the bond pays back only the principal of the bond, and the bondholder receives federal tax credits in lieu of the traditional bond interest. The tax credit may be taken quarterly to offset the tax liability of the bondholder.

Marine renewable energy technologies are an eligible energy resource under numerous states' **Renewable Portfolio Standards (RPS)** and voluntary renewable energy goals. This market-based mechanism requires utilities to source a percentage of their electricity from renewable resources. As of this writing, 29 states have RPS in place and 8 states have voluntary renewable energy goals or targets.

Many states also have **Public Benefit Funds (PBF)**, which are a state-level market support mechanism designed to provide continued support for renewable energy resources, energy efficiency initiatives, and low-income energy programs. The incentives for each PBF vary by state. MHK technologies can also benefit from funding opportunities through non-profits and public-private partnerships, such as the **Oregon Wave Energy Trust**.

PUBLIC FUNDING PROGRAMS

Department of Energy Water Power Technologies Office Marine and Hydrokinetic Program

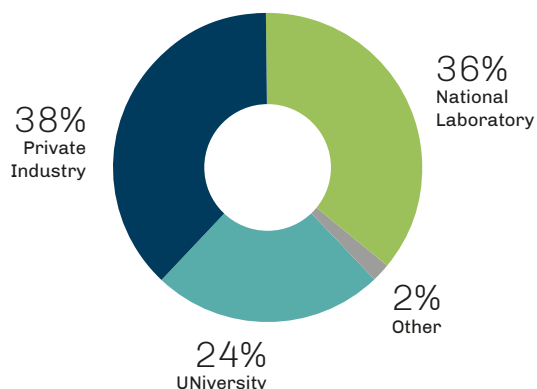
Since 2008, WPTO funding has been split roughly equally among private companies, universities, and the national labs. The bulk of WPTO funding to-date for marine renewable energy has been allocated toward wave energy research, followed by cross-cutting R&D that supports multiple resource types, and then current technologies (see charts).

Developers can seek DOE WPTO funding through several different competitive funding mechanisms: **Funding Opportunity Announcements (FOAs)** are competitive

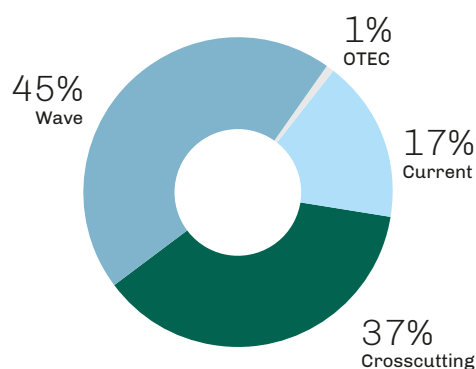
grants for industry, academia, or national laboratories to form partnerships in conducting research and testing. Some FOAs are available to international applicants. **Small Business Vouchers (SBV)** provide clean energy small businesses access to the state-of-the-art facilities and experts at participating DOE national laboratories (see Research & Development Section). **Small Business Innovation Research (SBIR)** and **Small Business Technology Transfer (STTR)** programs are methods through which federal agencies with large R&D budgets set aside a fraction of their funding for competitions among small businesses to pursue early stage research. Small businesses that win awards in these programs keep the rights to any technology developed and are encouraged to commercialize the technology. Lastly, DOE's **Technology Commercialization Fund (TCF)** leverages R&D funding in the applied energy programs, paired with private partners, to mature promising energy technologies with high impact potential.

WPTO identifies and funds qualified projects within specific topic areas that support program objectives, depending on available funds. In evaluating all proposals for new energy developments or new adaptations of existing technology, WPTO assesses whether individual applications clearly meet the goals of the topic area and their potential to advance the industry. More information on available funding opportunities at: <https://energy.gov/eere/water/water-power-funding-opportunities>

A recent FOA example is WTPO's April 2018 announcement of up to \$23 million to support marine energy technologies that aim to reduce capital costs and shorten deployment timelines. Funded research will further the development of technologies and result in cost reduction by (1) advancing early stage research and evaluation of next generation wave and tidal/current systems; (2) supporting early stage design of power take-off and control systems; and (3) developing tools and methodologies that capture recent advances in the scientific understanding of environmental impacts of marine renewable energy. To see other DOE funded projects, visit the online project database map at: <https://www.energy.gov/eere/water/water-power-technologies-office-projects-map>



PERCENT OF TOTAL FUNDING DISTRIBUTION BY RECIPIENT FY 2008-2018



PERCENT OF TOTAL FUNDING DISTRIBUTION BY RESOURCE TYPE FY 2008-2018

RESEARCH & DEVELOPMENT

There are numerous universities, private companies, organizations, non-profits, and national laboratories that actively support research on marine renewable energy in the United States. Collectively, these institutions represent approximately 40 unique testing facilities for marine energy research. To foster marine renewable energy technology research, education, and outreach, WPTO has partnered with five universities to operate three National Marine Renewable Energy Centers (NMRECs). These NMRECs are:

- **Pacific Marine Energy Center (PMEC):** Formerly known as the Northwest National Marine Energy Center, PMEC is a partnership between three universities in the Pacific Northwest: University of Washington, Oregon State University, and the University of Alaska Fairbanks. The organization coordinates access to marine energy test facilities across the region and works with stakeholders to address key challenges slowing the adoption of marine energy.
- **Hawaii National Marine Renewable Energy Center (HINMREC):** HINMREC is operated by the Hawaii Natural Energy Institute at the University of Hawaii: Manoa. Its primary objective is to facilitate the development and implementation of commercial wave energy systems. HINMREC helps with the management of two test sites in Hawaii, WETS and the OTEC Test Site (see Open Sea Test Sites section).
- **Southeast National Marine Renewable Energy Center (SNMREC):** SNMREC is operated by the Florida Atlantic University. Although SNMREC has research interests in all marine renewables, it places an emphasis on those resources available to the South Eastern United States: ocean currents and offshore thermal energy conversion.

DOE's national laboratories possess unique instruments and facilities capable of addressing large-scale, complex R&D challenges with research expertise and an approach emphasizing translating basic science to innovation. WPTO partners with several of these laboratories to support R&D in marine renewable energy, examples of research efforts include:

- **Sandia National Laboratories (SNL):** SNL conducts research on advanced controls, simulation of marine renewable energy environmental impacts, advanced materials for coatings and construction, testing and simulation of technologies, and resource characterization.
- **National Renewable Energy Laboratory (NREL):** NREL's water power program conducts research on energy markets, grid integration, resource characterization and mapping, design and simulation, technology evaluation and validation, as well as performing full-scale validation tests on systems and components.
- **Pacific Northwest National Laboratory (PNNL):** PNNL conducts research on environmental impacts, resource

characterization and modeling, advanced materials and manufacturing, monitoring techniques and data gathering, and education outreach. PNNL is also responsible for implementing Annex IV under OES on behalf of WPTO.

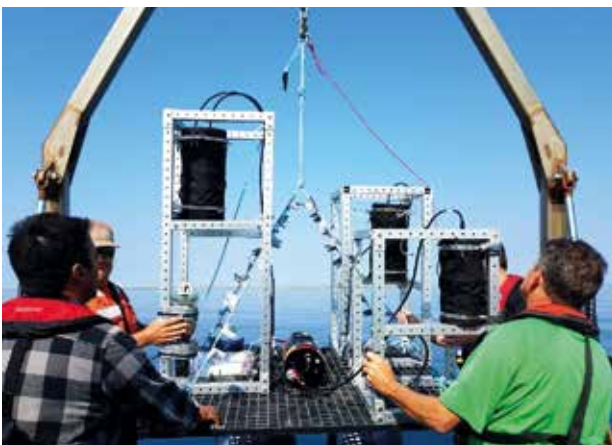
- **Oak Ridge National Laboratory (ORNL):** ORNL conducts research on environmental impacts of instream technology, advanced materials for coatings and construction, design for manufacturing, and assessment of stream resources.

R&D HIGHLIGHTS

- In June 2018, WPTO announced six awardees selected to receive a total of \$6.7 million in federal funding. The **Igiugig Village Council (IVC)** in Alaska, in partnership with the **Ocean Renewable Power Company**, was selected to receive \$2.3 million to further design, construct, and test the RivGen cross-flow river current turbine system. Awardees for the other five projects to receive funding include: **Resolute Marine Energy**, **Oscilla Power, Inc.**, **Enorasy**, and the **University of Alaska - Fairbanks**.
- During 2018, **Ocean Power Technologies** brought to market a new suite of products—including a subsea battery energy storage system and a hybrid model of their wave energy converter (WEC), the PowerBuoy. Also in 2018, Ocean Power Technologies signed an agreement with Enel Green Power to evaluate deploying a PowerBuoy system along the coast of Chile.
- In January 2018, Ocean Energy USA (OE) announced that it will construct its 1 MW oscillating water column device at Vigor Shipyard in Oregon. This project is jointly funded by WPTO and the **Sustainable Energy Authority of Ireland (SEAI)** and demonstrates the value of international collaboration. The OE Buoy is currently under construction at the shipyard and once complete will be towed to the U.S. Navy's WETS in Hawaii for testing.
- The ocean energy research team at **NREL** applied their broad expertise in ocean engineering, structural dynamics, fluid mechanics, and control systems to conceive an innovative wave converter concept that could control loads in highly energetic seas while maintaining power production. This new variable geometry wave converter concept was recently awarded a patent by the U.S. Patent Office, No. 10066595 B2. Soon, the NREL team will be working with WEC developers in the United States to explore approaches for applying variable geometry concepts to industry designs to improve performance and lower the cost of energy.
- In May 2018, **SNL** completed wave tank testing at the Navy's Maneuvering and Sea Keeping (MASK) basin to investigate the implementation and performance

of a series of closed-loop WEC power take-off (PTO) controllers. The latest project results were presented in July 2018 at the Advanced Research Projects Agency - Energy (ARPA-E)-hosted workshop, “Control Co-Design for Wind and Marine Hydro-Kinetic Energy Systems.” SNL’s work in advanced WEC dynamics and controls demonstrates the opportunity for substantial reductions in the levelized cost of energy helping to increase competitiveness of these devices.

- From April through July of 2018, WPTO collected public comments on its draft report, **Potential Maritime Markets for Marine and Hydrokinetic Technologies**. The report details the economic and technical landscapes of 14 different non-grid markets for marine energy technologies. These markets include applications such as ocean observation, unmanned underwater vehicle recharging, offshore aquaculture, seawater desalination, or coastal disaster relief. The draft report received over 400 unique comments, and a final report that includes this feedback will be released in 2019.
- A research group from Integral Consulting, Inc. working in coordination with **PNNL**, performed a sequence of tests using a new sensor package, NoiseSpotter, which is designed to record sound generated by marine renewable energy devices. This will provide important information related to the potential environmental effects on marine animals of sound generation from these devices. This work is part of the **Triton Initiative**, which supports the development of advanced and cost-effective environmental monitoring technologies for marine renewable energy applications. For more information visit: <https://triton.pnnl.gov/>



- WPTO is a supporting body of the U.S. Technical Advisory Group to the International Electrotechnical Commission (IEC) Technical Committee (TC) 114. The IEC TC 114 – which comprises more than 190 subject matter experts representing 27 countries – has published 10 technical specifications as of 2018 and expects to publish an additional 4 technical specifications in 2019. More information can be found at: <http://www.tc114.us/>

TECHNOLOGY DEMONSTRATION

OPERATIONAL PROJECTS

- **Fred Olsen**: The BOLT Lifesaver, a point-absorber device, was redeployed in October 2018. For this deployment the BOLT Lifesaver underwent modifications to host an oceanographic sensor package (Adaptable Monitoring Package), developed by the Pacific Marine Renewable Energy Center, to demonstrate the WEC’s ability to directly power external systems. The BOLT Lifesaver has multiple PTO units, each rated for a capacity of 10 kW. As of this writing, the device has been operational for 96 days and generated over 6,800 kWh.
- The **Living Bridge Project** is an interdisciplinary smart infrastructure research project led by the University of New Hampshire. The project has converted the Memorial Bridge into a demonstration “smart bridge” by equipping it with structural health monitoring and environmental sensors on its structural elements and in the tidal Piscataqua River. To power these sensors and offset energy usage on the bridge, a 25 kW cross-flow vertical axis tidal turbine has been installed beneath the bridge on a turbine deployment platform designed and built by the University of New Hampshire Center for Ocean Renewable Energy. The cross-flow turbine was supplied by New Energy Corporation of Calgary, Alberta and has been in operation since June 2018; it will remain deployed for one year under this project.

PLANNED DEPLOYMENTS

- **Ocean Energy USA (OE)**: A 1-megawatt OE Buoy, an oscillating water column design, is currently under construction at Vigor Shipyard in Oregon and is slated for testing in 2019 at WETS. The deployment will last approximately one year and will provide useful performance data for model validations, reliability performance, and opportunities for cost reductions.



- **Columbia Power Technologies (C-Power)**: C-Power has completed physical testing of its novel, direct-drive PTO at NREL. The PTO, which includes a 6.5 m diameter, 4 mm airgap, permanent-magnet 500 kW generator, is being updated in preparation for use in their grid-

connected, open-water demonstration project at WETS, starting in the later-half of 2019. This one year deployment will provide valuable reliability data, as well as indicate opportunities for design improvements and optimization. C-Power will begin fabrication of their StingRAY H2 WEC device for WETS in early 2019. C-Power has also commenced physical testing at NREL of mixed-material (composite and metal) hull components for its structural optimization project and initiated an advanced controls project with SNL; both projects will be completed in 2019.



- Northwest Energy Innovations (NWEI):** NWEI's Azura™ is a multimode, point absorber WEC that extracts power from both the heave and surge motions of waves to maximize energy capture. NWEI previously tested their technology in Oregon in 2012, and a half-scale device was tested with 98% availability for 19 months beginning in June 2015 at the 30-m berth at WETS. NWEI redeployed their full-scale system at WETS this past February 2018 and is aiming to deploy again in 2020 or 2021.



- Verdant Power:** Verdant's Fifth Generation Kinetic Hydropower System (Gen5 KHPS) is an axial flow current-capturing turbine system. Verdant and its partners are working on the design of a TriFrame that optimizes turbine spacing and structural requirements to allow for cost-effective installation, operation, maintenance, and retrieval. Verdant plans to test this new system along with their Gen5 KHPS at their pilot project site in the East River near New York City. This project will advance understanding of optimal turbine spacing and best practices for installation, maintenance, and retrieval of underwater turbines. Following the successful demonstration of the TriFrame system in 2020, Verdant is considering converting the Roosevelt Island Tidal Energy project to a fully functioning world-class test and demonstration facility for distributed generation, energy storage, and electric vehicle charging stations, while executing its global commercial launch.



- Ocean Renewable Power Company:** Igiugig Village of Alaska is partnering with Ocean Renewable Power Company (ORPC) to develop the RivGen Power System, a submerged cross-flow river current turbine system. In 2014, WPTO funded a successful demonstration of ORPC's RivGen turbine and has decided to provide additional support to deploy and operate a next-generation RivGen Power System in 2019. The project will serve as an example to remote locations on how they

can reduce energy costs and offset diesel generation using marine energy.

- **Ocean Power Technologies (OPT)** has a contract to supply Oil & Gas company, Premier Oil, with one of its PowerBuoy systems for the deployment in an oil and gas field in the Central North Sea. The PowerBuoy will serve as an intelligent platform to provide communications and remote monitoring services at the site in support of Oil & Gas operations. OPT is targeting a deployment date in the summer of 2019.
- **Oscilla Power:** Oscilla Power is developing a point absorber with a heave plate type WEC called the Triton WEC. The company has done extensive testing at scale and recently concluded WPTO-funded testing on survivability design methodologies. The company is aiming to test their system in the second half of 2019 at WETS in Hawaii.
- Both **AquaHarmonics** and **CalWave**, first and second-place winners of the 2016 Wave Energy Prize respectively, have been advancing their designs. Both companies are aiming to deploy scaled-systems at WETS in the coming years.



RELEVANT NATIONAL EVENTS

In May 2018, Washington, D.C. was once again the host of **Waterpower Week**. This annual event —of which WPTO is a core contributor—brings together three events under one roof: National Hydropower Association’s Annual Conference, the International Marine Renewable Energy Conference, and the Marine Energy Technology Symposium. The three-day conference had discussions on non-grid scale markets, modelling, cost reduction strategies, and advanced controls, just to name a few. Additionally, more than 30 presentations and posters by WPTO staff, national laboratories, and WPTO funding awardees were presented. Information on the event, including some presentations can be found at: <https://www.energy.gov/eere/water/articles/wpto-waterpower-week-washington-2018>

In June 2018, the United States was selected as the host country for the 2020 **International Conference on Ocean Energy**. The event will be held in Washington, D.C. This is the first time the event has been held in the United States and will serve as an excellent opportunity to bring in international knowledge and expertise to advance marine energy both domestically and abroad. DOE will share U.S. expertise in marine energy technologies research, development, and testing at the event.

06

APPENDIX 1

MEMBERSHIP OF THE EXECUTIVE COMMITTEE

CABINET 2018

CHAIRMAN

2017 - 2020

Mr. Henry Jeffrey
The University of Edinburgh
United Kingdom

VICE-CHAIR

Dr. Annie Dallman
Sandia National Laboratories
USA

VICE-CHAIR

Mr. Yann-Hervé De Roeck
France Energies Marines
France

SECRETARY

Dr. Ana Brito e Melo
WavEC Offshore Renewables
Portugal

AUSTRALIA

DELEGATE Dr. Mark Hemer
CSIRO Oceans and Atmosphere

ALTERNATE Mrs. Stephanie Thornton
Australian marine Energy Taskforce (AMET)

BELGIUM

DELEGATE Dr. Ludovic Mouffe
Federal Public Service Economy

ALTERNATE Prof. Julien de Roeck (*until October 2018*)
Dr. Vicky Stratigaki (*since November 2018*)
Ghent University

CANADA

DELEGATE Mr. Ghanashyam Ranjitkar
Natural Resources Canada

ALTERNATE Mrs. Monika Knowles
Natural Resources Canada

CHINA

DELEGATE Mr. Peng Wei
National Ocean Technology Center, SOA

ALTERNATE Mr. Wang Ji
National Ocean Technology Center

DENMARK

DELEGATE Mrs. Hanne Thomassen
Energistyrelsen

ALTERNATE Dr. Kim Nielsen
Ramboll

EUROPEAN COMMISSION

DELEGATE Dr. Ir. Matthijs SOEDE
European Commission DG Research & Innovation

ALTERNATE Dr. Davide MAGAGNA
European Commission DG Joint Research Centre

FRANCE

DELEGATE Mr. Yann-Hervé De Roeck
France Energies Marines

ALTERNATE Mr. Kelly Cayocca
France Energies Marines

GERMANY

ALTERNATE Mr. Jochen Bard
Fraunhofer Institute for Energy Economics and Energy
Systems Technology IEE

INDIA

DELEGATE Dr. M. A. Atmanand
National Institute of Ocean Technology

ALTERNATE Dr. Purnima Jalihal
National Institute of Ocean Technology

IRELAND

DELEGATE Mr. Declan Meally
Sustainable Energy Authority of Ireland

ALTERNATE Mrs Patricia Comiskey
Sustainable Energy Authority of Ireland

ITALY

DELEGATE Mr. Luca Benedetti
Gestore dei Servizi Energetici (GSE)

JAPAN

DELEGATE Dr. Yasuyuki Ikegami
Institute of Ocean Energy, Saga University

ALTERNATE Dr. Shuichi Nagata
Institute of Ocean Energy, Saga University

KOREA

DELEGATE Mr. Man Wook Hoe
Ministry of Oceans and Fisheries

ALTERNATE Dr. Jin-Hak Yi
Korea Institute of Ocean Science & Technology

MEXICO

DELEGATE Mr. Rodolfo Silva Casarín
CEMIE – Océano

ALTERNATE Dr. Juan Carlos Alcéreca Huerta
CEMIE – Océano

MONACO

DELEGATE HE Bernard Fautrier
Government of the Principality of Monaco

ALTERNATE Mr. Sébastien Lubert
Fondation Prince Albert II de Monaco

NETHERLANDS

DELEGATE Mr. H.W. Boomsma
Ministry of Economic Affairs

ALTERNATE Mr. H.P.E.M. Reijnders
Netherlands Enterprise Agency

NEW ZEALAND

DELEGATE Dr Craig Stevens
National Institute for Water and Atmospheric Research
(NIWA)

ALTERNATE Mr. Gareth Gretton
AWATEA

NORWAY

DELEGATE Mr. Harald Rikheim
Norges Forskningsråd

PORTUGAL

DELEGATE Dr. Paulo Justino (*until October 2018*)
Laboratório Nacional de Energia e Geologia (LNEG)

Prof. Luis Gato (*since November 2018*)
Instituto Superior Técnico (IST)

ALTERNATE Prof. António Falcão
Instituto Superior Técnico (IST)

SINGAPORE

DELEGATE Prof. Subodh Mhaisalkar
Energy Research Institute

ALTERNATE Dr Srikanth Narasimalu
Energy Research Institute

SOUTH AFRICA

DELEGATE Dr Thembakazi Mali
SANEDI

SPAIN

DELEGATE Mr. Luis Hilario Alonso Mijares
Ministerio de Industria, Turismo y Comercio

ALTERNATE Mr. Jose Luis Villate (*until June 2018*)
TECNALIA

Mr. Yago Torre-Enciso (*since July 2018*)
BiMEP

SWEDEN

DELEGATE Ms. Maria Olsson
Swedish Energy Agency

ALTERNATE Mr. Lars Karlbom
Swedish Energy Agency

UK

DELEGATE Mr. Trevor Raggatt
Department of Energy and Climate Change

ALTERNATE Mr. Henry Jeffrey
The University of Edinburgh

USA

DELEGATE Mr. Tim Ramsey
U.S. Department of Energy

ALTERNATE Dr. Annie Dallman
Sandia National Laboratories

APPENDIX 2

EXECUTIVE COMMITTEE MEETINGS

MEETING	DATE	LOCAL	COUNTRY
1	19 October 2001	Paris	FRANCE
2	21 - 22 March 2002	London	UK
3	31 October 2002	Brighton	UK
4	4 March 2003	Paris	FRANCE
5	15 - 16 September 2003	Cork	IRELAND
6	26 - 27 February 2004	Lisbon	PORTUGAL
7	4 - 5 November 2004	Copenhagen	DENMARK
8	4 March 2005	Paris	FRANCE
9	16 - 17 November 2005	Brussels	BELGIUM
10	1 - 3 May 2006	Vancouver	CANADA
11	14 - 15 November 2006	Lisbon	PORTUGAL
12	20 - 21 March 2007	Mexico City	MEXICO
13	16 - 17 October 2007	Messina	ITALY
14	15 - 16 April 2008	New York city	USA
15	13 - 14 October 2008	Brest	FRANCE
16	30 - 31 March 2009	Bilbao	SPAIN
17	4 - 5 September 2009	Oslo	NORWAY
18	22 - 23 April 2010	Wellington	NEW ZEALAND
19	30 Sep - 1 Oct 2010	Dublin	IRELAND
20	26 - 27 April 2011	Washington DC	USA
21	13 - 14 September 2011	Madeira	PORTUGAL
22	17 - 18 May 2012	Daejeon	KOREA
23	22 - 23 October 2012	Aalborg	DENMARK
24	14 - 15 May 2013	Guangzhou	CHINA
25	22 - 23 October 2013	Cape Town	SOUTH AFRICA
26	13 - 14 May 2014	Paris	FRANCE
27	10 - 11 November 2014	Halifax	CANADA
28	12 - 13 May 2015	Kassel	GERMANY
29	11 - 12 November 2015	Cancun	MEXICO
30	9 - 10 May 2016	Gothenburg	SWEDEN
31	20 - 21 October 2016	Singapore	SINGAPORE
32	10 - 11 April 2017	Monaco	MONACO
33	14 - 15 November 2017	Chennai	INDIA
34	14 - 15 June 2018	Cherbourg	FRANCE
35	29 - 30 November 2018	Las Palmas	SPAIN
NEXT MEETING			
36	26 - 27 March 2019	Riviera Maya	MEXICO

CONTACTS

WavEC - Offshore Renewables

Rua D. Jerónimo Osório, 11, 1º andar, 1400-119, Lisbon
PORTUGAL

www.ocean-energy-systems.org

The **International Energy Agency (IEA)** works to ensure reliable, affordable and clean energy for its 29 member countries and beyond. Founded in 1974, the IEA was initially designed to help countries co-ordinate a collective response to major disruptions in the supply of oil such as the crisis of 1973/4. While this remains a key aspect of its work, the IEA has evolved and expanded. It is at the heart of global dialogue on energy, providing authoritative statistics and analysis.

The IEA examines the full spectrum of energy issues and advocates policies that will enhance the reliability, affordability and sustainability of energy in its 29 member countries and beyond. The four main areas of focus are:

- energy security: promoting diversity, efficiency and flexibility within all energy sectors
- economic development: ensuring the stable supply of energy to IEA member countries and promoting free markets to foster economic growth and eliminate energy poverty
- environmental awareness: enhancing international knowledge of options for tackling climate change
- engagement worldwide: working closely with non-member countries, especially major producers and consumers, to find solutions to shared energy and environmental concerns.

Technology Collaboration Programmes (TCPs) are independent, international groups of experts that enable governments and industries from around the world to lead programmes and projects on a wide range of energy technologies and related issues. TCPs currently cover topics related to:

- efficient end-use (buildings, electricity, industry, transport)
- cleaner fossil fuels (greenhouse-gas mitigation, extraction, supply, transformation)
- renewable energy and hydrogen (technologies and policies for deployment)
- cross-cutting issues (modelling, technology transfer, project financing)
- fusion power (safety, physics, materials, technologies).

The 6000 experts in the TCPs work to advance the research, development and commercialisation of energy technologies. The scope and strategy of each TCP is in keeping with the IEA Shared Goals of energy security, environmental protection and economic growth, as well as engagement worldwide.

