OCEAN ENERGY SYSTEMS

ANNUAL REPORT

AN OVERVIEW OF OCEAN ENERGY ACTIVITIES IN

2019

Technology Collaboration Programme
by iea

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CHAIRMAN'S MESSAGE

MR. HENRY JEFFREY
University of Edinburgh, United Kingdom
OES Chairman

A warm welcome to the 2019 OES Annual Report. As we stand at the doors of another exciting decade for the ocean energy sector, I trust you will find this report informative and useful.

Several milestones have been achieved in the 2009-2019 decade. These range from the commissioning of the world's largest grid-connected tidal barrage and wave power plants in Sihwa Lake, South Korea and Mutriku, Spain respectively, through numerous wave and tidal stream devices deployed in open-sea waters for testing, to the establishment of push and pull mechanisms to stimulate the ocean energy sector in various regions of the world. Within this past decade, the cumulative energy produced from wave and tidal stream energy alone has increased from less than 5 GWh in 2009 to approx. 45 GWh in 2019.

These achievements would have not been possible without the fundamental support of the OES member countries, to whom I would like to heartily thank for their time and contributions to this year's report. The countries' work conveys sizeable and global ongoing efforts to identify potential commercialisation pathways for ocean energy technologies and support to the development of the sector.

In North America, Canada amended its Marine Renewable Energy Act to extend feed-in-tariffs and Purchasing Power Agreements for tidal energy developers working in FORCE. Meanwhile, the US officially launched the new R&D initiative "Powering the Blue Economy" seeking to relieve power constraints in emerging coastal and off-grid markets through marine renewable energy and promote economic growth.

Similarly, Europe sees ocean energy as a means to meet decarbonisation target, foster economic growth, and create employment opportunities and has supported the development of the sector through its Strategic Energy Technology (SET) Plan and the Blue Growth Strategy. Spain continued its support to ocean energy technologies enabling a series of deployments and drafting ocean energy targets for 2025 (25 MW) and 2030 (50 MW). Scotland actively supported the development of ocean energy technologies through the establishment of the £10m Saltire Tidal Energy Challenge Fund. Moreover, the UK enabled the development and testing of several prototype devices including Orbital O2, Minesto's Deep Green, Magallanes Renovables' ATIR, and Marine Power Systems' WaveSub.

Also aiming to sustainable use ocean energy resources for economic growth, Australia announced funding for a 10-year $AUD 330m Blue Economy Cooperative Research Centre and the preparation of a new marine and coastal policy in Victoria, one of the eight Australian states.

In Asia, India has made tidal, wave and OTEC technologies eligible for Renewable Purchase Obligations while Korea completed a short-term OTEC demonstration in the East Sea. In addition, China sought to foster the tidal current energy sector through a temporary feed-in tariff of €0.33/kWh. The LHD tidal current energy project will be the first beneficiary of this incentive.

This support goes in hand with global efforts to limit global warming. Decarbonisation has been appointed as the main strategy to tackle this challenge. Many countries around the world have revised or set ambitious targets for emission reductions and the production of electricity from renewable resources. Ocean energy could contribute to attaining these targets while creating synergies to aid in tackling sustainable development challenges as well.

Several challenges lie ahead for ocean energy, nonetheless: affordability, reliability, installability, operability, funding availability, capacity building, and standardization to name a few. Particularly, significant cost-reductions are required for ocean energy technologies to compete with other low-carbon technologies. The European SET-Plan aims to demonstrate deployment of ocean energy at commercial scale and drive down costs, aiming at LCOE targets of 10 ct€/kWh and 15 ct€/kWh in 2030 for tidal stream and wave respectively.

The start of a new decade carries considerable promise for ocean energy. Important projects and deployments are planned for the coming years and more and more governments across the globe are showing interest and supporting ocean energy technologies. Certainly, this will be another fruitful decade for the sector.

To end, I would like to thank Yann-Hervé De Roeck, vice-chair of the OES, and Ana Brito e Melo, Executive Secretary, for all their work and time invested in putting together this report.

The start of a new decade carries considerable promise for ocean energy. Important projects and deployments are planned for the coming years and more and more governments across the globe are showing interest and supporting ocean energy technologies. Certainly, this will be another fruitful decade for the sector.

EXECUTIVE SUMMARY

ANA BRITO E MELO
OES Executive Secretary

Introduction

The Technology Collaboration Programme (TCP) supports the work of 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. The experts in these collaborations work to advance the research, development and commercialisation of energy technologies. The scope and strategy of each collaboration is in keeping with the IEA Shared Goals of energy security, environmental protection and economic growth, as well as engagement worldwide.

The Technology Collaboration Programme was created with a belief that the future of energy security and sustainability starts with global collaboration. The programme is made up of 6,000 experts across government, academia, and industry dedicated to advancing common research and the application of specific energy technologies.

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

The OES connects organisations and individuals working in the ocean energy sector to accelerate the viability, uptake and acceptance of ocean energy systems in an environmentally acceptable manner. The work of the OES covers all forms of energy generation in which sea water forms the motive power through its physical and chemical properties, i.e. wave, tidal range, tidal and ocean currents, ocean thermal energy conversion and salinity gradients.

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 2019. 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 2019. 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.

OES has a close link with the International Conference on Ocean Energy (ICOE), held every two years, and leads a competitive process to select the host team for this conference. In 2019, the host for the 8th edition of ICOE was approved by the OES Executive Committee: ICOE 2020 is scheduled to take place on May 19-21 2020 at the Marriott Marquis Washington, D.C., hosted by the National Hydropower Association (NHA), a non-profit North-American national association dedicated to promoting the growth of clean, affordable waterpower in all of its forms, ranging from conventional hydropower to pumped storage to marine energy.

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OES Key Achievements in 2019

The OES held two ExCo Meetings in 2019: The 36th and 37th meetings were convened in Riviera Maya, Mexico (26 – 27 March 2019), hosted by Cémie-Oceano, and in Dun Laoghaire, Dublin, Ireland (2 - 3 October), hosted by the Sustainable Energy Authority of Ireland, and organised in the same week as the annual Ocean Energy Europe Conference and Exhibition, one of the most important events on Europe's ocean energy calendar that took place in Dublin.

During 2019, the task on environmental issues has been renamed to **OES-Environmental (OES-E)**. Fifteen nations participate in this task, led by the US Department of Energy (DOE) and implemented by the Pacific Northwest National Laboratory. Over the year information has been collected from baseline data and monitoring efforts around deployed marine energy devices; Tethys[1], the publicly accessible knowledge management system has been continuously updated with papers, reports, and other media on environmental effects of marine energy devices; there has been several actions towards outreach and engagement to the ocean energy community, with particular emphasis on researchers, regulators, and developers.

On the **Cost of Energy for Ocean Energy Technology**, a new study led by Tecnalia from Spain was concluded in 2019. 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 developments and differences among technologies and countries. The findings of this study have been shared with the IEA for their modelling work in renewable energies.

OES has two tasks dedicated to the **modelling verification and validation of ocean energy technologies**, one led by Ramboll in Denmark, for wave energy, and a second one, for tidal energy, led by the Energy Research Institute at Nanyang Technological University, Singapore. 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, 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. A workshop with the support of OES has been organised during the 7th International OTEC Symposium in Busan, Republic of Korea.

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

1 https://tethys.pnnl.gov/

accepted approach. A draft report discussing the benefits of common evaluation approaches in the ocean energy sector and the use of common language has been prepared to help build consensus. It details the evaluation process and how it changes throughout the technology development process.

In 2019, the ExCo commissioned a new study to assess the **number of jobs related to the development of the ocean energy sector**, coordinated by France Energies Marines. The assessment of the number of jobs related to the development of the ocean energy sector has reached utmost importance for decision makers. Some figures have been announced but an accurate assessment of existing jobs directly related to the sector needs specific attention. One difficulty to properly assess the number of jobs relies on the methodology applied. The proposed project thus aims to provide both a methodology and actual figures of job assessment with an indication of the robustness of the models used, their limitations and the quality of their outputs.

A third workshop **on ocean energy in insular conditions**, aiming to discuss barriers and opportunities, was organised at the East-West Center in Honolulu, Hawaii, USA (2-3 May 2019) by the Oceanic Platform of the Canary Islands (PLOCAN), with the support of OES.

OES also supported in 2019 a workshop on **open-sea testing** organized by the International WaTERS network at EMEC on Orkney Islands, Scotland, to exchange information and experience on all aspects of planning, development and operation of open-water test facilities. The International WaTERS network brings together operational and planned test sites from around the world to discuss common issues and agree actions for collaborating for the good of marine energy.

Country Highligths in 2019

Australia

- Engagement in the Australian ocean energy sector has continued to grow in 2019 with the announcement in April 2019 of a $330 million research project **Blue Economy Cooperative Research Centre (CRC)**, to support sustainable growth of Australia's blue economy. One of the five streams within the Centre is "Offshore Renewable Energy Systems".
- The **Australian Ocean Energy Group (AOEG)**, a virtual ocean energy cluster, was formally launched in 2019 and hosted the *Ocean Energy Market Development Summit* to discuss customer-pull and industry-push mechanisms in an effort to increase the number of ocean energy development projects across Australia.
- Wave and tidal technology projects continued to progress in 2019:
  - **MAKO tidal device** was tested in the Port of Gladstone, on Australian's east coast;
  - **Wave Swell Energy** began construction of their 250 kW wave energy device;
  - **Carnegie Clean Energy** has been constructing their CETO 6 device;
  - Four international companies began investigating opportunities for ocean energy projects in Australia.
- In the course of feasibility studies for tidal energy development in Australia, two sites have been identified for commercial development: the Banks Strait in Tasmania and the Clarence Strait in northern Australia.

Belgium

- Diverse initiatives on the Blue Economy are being developed with the support of the Flemish Government: **Blue Accelerator** is the new offshore maritime innovation and development platform funded by the European Regional Development Fund (ERDF) and within this platform a Living Lab, based in Ostend, is under development, for testing under real sea conditions. **NEMOS** Wave Energy Converter has been tested there.
- Every year, the West Flanders Development Agency (**POM West Flanders**) launches a call for short-term innovation cooperation projects called the "Quick Wins", with the ambition to fund a pilot installation, test setup or prototype. POM West-Flanders implements the socio-economic policy of the Province of West-Flanders, focusing on the themes of innovation, entrepreneurship, transport & logistics and the labour market.
- POM introduced in 2019 the **TUA West - Technical University Alliance** for economic transformation in West-Flanders, acting as a liaison between industry and civil society. Within this initiative, a test infrastructure located in West Flanders is being encouraged to be used in favour of the Blue Energy sector.
- A network of Flemish companies known as **IBN-Offshore Energy** are developing activities oriented towards facilitating innovation in the field of offshore energy.

- The **Blue Cluster** has been created with a number of entities promoting economic activities in the sea, some of them involved in wave and tidal energy projects such as DEME Blue Energy, IMDC, Laminaria, Tractebel, among others.
- The European COST Action **"WECANet"** is a network of 31 countries dedicated to Marine Renewable Energy, with a focus on wave energy, coordinated by the Coastal Engineering Research Group of Ghent University. In 2019, WECANet funded a number of research collaborations, training courses, dissemination activities and scientific publications on wave energy.
- Five European clusters, including Flanders' Maritime Cluster, joined efforts in the **ELBE project** supported by the EU COSME-programme aiming at positioning Europe as the technological and industrial world leader in blue energy, with a focus on wave energy, tidal energy and offshore wind.
- One Flemish wave energy developer, **Laminaria**, is developing a 200 kW prototype that has been tested at EMEC.

Canada

- Over the course of 2019, the Government of Canada focused on progressing and implementing a number of key priorities – several of which had relevance to the marine renewable energy sector. In June 2019, new legislation affecting regulation of the energy sector and marine renewable energy was approved.
- Relevant tidal energy development continues on the Atlantic coast in the province of Nova Scotia. To date, 7 MW have been allocated: 5 MW to Big Moon Power in 2018, 2 MW to Jupiter Hydro in 2019 and 1.5 MW allocated to Nova Innovation in 2019.
- DP Energy, Sustainable Marine Energy, Minas Tidal, Big Moon Power, Jupiter Hydro, and Nova Innovation have received permits from the Government of Nova Scotia for development in the province and are all working towards deployments in the next 1-2 years. The Government of Canada has also had a huge impact in supporting these projects and more recently awarded DP Energy $29.7 million for the 9 MW Uisce Tapa project being developed at FORCE.
- Other regions of Canada are also making progress in tidal, wave, and river current energy – many with a focus on providing clean electricity to remote communities.
- In 2019 a new funding programme was introduced – ***Breakthrough Energy Solutions Canada***. In partnership with Breakthrough Energy, Natural Resources Canada (NRCan) launched a $30 million call for proposals.
- **Big Moon Power** completed another successful summer of prototype testing in Nova Scotia Bay of Fundy and is now planning to commence prototype testing in New Brunswick.
- **Sustainable Marine Energy (SME)** has continued to ramp up its operations in Nova Scotia following the successful installation of their 280 kW demonstrator in Grand Passage, Bay of Fundy. SME will be developing its 9 MW Pempa'q project at FORCE which will be delivered and operated by Spicer Marine Energy, a joint venture between SME and Minas Tidal Ltd.
- **Yourbrook Energy Systems Ltd** continued testing its 40 kW prototype in Juskatla Narrows on Haida Gwaii, British Columbia.
- **DP Energy** has continued to progress the Uisce Tapa project through 2019 at the Fundy Ocean Research Center for Energy (FORCE). The project is a 6 turbine, 9 MW array using the Andrtiz Hammerfest Hydro Mk1 turbine.
- **Jupiter Hydro** was awarded two permits from Nova Scotia Department of Energy and Mines for an in-stream tidal energy project in the Bay of Fundy and has begun the process of detailed design.
- **Nova Innovation**, over the course of 2019, carried out multiple activities to support its proposed Petite Passage Tidal Project, including extensive stakeholder engagement and mapping of supply chain options.
- **ORPC Canada** is completing a feasibility study and community outreach initiative for a site assessment of the Great Whale River in Québec.
- **Oneka Technologies** has been focused on producing and commercializing autonomous desalination units using wave energy.

> On the east coast of Canada, the success of policy and other supports is evident with the Bay of Fundy's world-class tidal resource attracting the interest of developers from around the world.

China

- A feed-in tariff of about €0.33/kWh for the LHD tidal current energy project was approved in 2019. This is the first ocean energy project benefiting from the temporary feed-in tariff policy. **LHD Tidal Current Energy Demonstration** project continues to progress and reached in September 2019 a cumulative power generation exceeding 1.5 GWh, since 2016.
- Over 20 institutes and universities have been involved in tidal current energy studies and have developed several prototypes from 60 kW to 650 kW. Most of the prototypes were deployed near Zhoushan Islands for testing.
- The **Zhoushan tidal current energy demonstration project** with an overall budget of RMB 144 million has been developed by the China Three Gorges (CTG) Corporation with national funding. In 2019, CTG completed construction of the 300 kW tidal current energy turbine, which is expected to be deployed soon.
- **Zhejiang University (ZJU)** is developing a Tidal Current Energy Demonstration Platform and in the period from 2015 to 2019 has deployed, near Zhairuoshan Island, 3 prototypes (60 kW, 120 kW, 650 kW) for open sea test.
- In September 2019, **NOTC Floating testing Platform** of small-scale H-axis turbines was deployed in Weihai test site.
- During 2019, a Chinese consortium started the construction of two wave energy platforms (500 kW) for testing in the new test site - **Wanshan Wave Energy Demonstration Project** – a first MW-level test site supported by the Government with an overall budget of RMB 151 million.
- The Guangzhou Institute of Energy Conversion (GIEC) has completed the first open sea test of their floating wave energy platform - "**sharp Eagle**" - which has been successfully connected to the power grid of a remote island.
- China is investigating the use of ocean energy systems to support offshore aquaculture. GIEC successfully built the first semisubmersible **offshore aquaculture cage "Penghu"**, integrating wave energy, which was deployed at the sea in June 2019.
- The **Chaohu Silver Ring Navigation Buoy Co.** is developing maritime buoys powered by wave energy, and already deployed several of these buoys in the sea during 2019.

Denmark

- The Danish Partnership for Wave Power includes nine active wave energy developers of which two have been testing prototypes at sea recently.
- **Wavepiston** completed two years of testing at the DanWEC test site facing the North Sea and will move now to test in PLOCAN, Gran Canaria.
- **CrestWing** wave energy prototype, named Tordenskiold, has been tested in Kattegat. In May the prototype was towed to port for maintenance and improvements, before re-deployment for further testing in 2020.
- The Danish wave energy developer **Floating Power Plant** is currently working with consenting and project development in England, Scotland and in Ireland with DP energy.
- During 2019, the German developer **NEMOS** received a draft permission from the Danish Energy Agency to start of tests at the Hanstholm test site, planned to start in 2020.
- DanWEC and Aalborg University (AAU) are partners in the Ocean Energy Scale-Up Alliance (OESA), a 3-year project, initiated in January 2019 with 13 partners managed by the Dutch Marine Energy Centre (DEMEC).

European Commission

- The European Commission continued to support ocean energy development via their funding programmes like Horizon 2020 and the European Regional Development Fund. **Horizon Europe** will be the successor of Horizon 2020 with an initial budget proposal of €100 billion for Research and Innovation.
- Since its inception in 2014, the H2020 programme has provided more than €165 million for ocean energy R&D to 44 different projects. Currently, Horizon 2020 funds 19 R&D projects on ocean energy.
- In 2019, three **new Horizon 2020 projects** were launched: "LiftWEC" for the development of a new class of wave energy converters led by Queen's University of Belfast; "Element" for the lifetime extension of tidal energy at Scotland's Shetland Tidal Array led by Nova Innovation and "NEMMO" with a focus on the development of tidal turbine blades.
- "**Blue Economy annual report 2019**" was published in May 2019 - this report examines the role of emerging sectors, including ocean energy, and the opportunity that they bring for attracting investments and potential future deployments.
- Two relevant initiatives have a focus on ocean energy: "**Clean Energy for EU Islands**" launched in 2017, which is a policy initiative for the investigation of the use of ocean energy technologies on EU islands, especially when coupled with energy storage facilities; also the **EU Island Facility** is a new Horizon 2020 project set up with the goal of mobilising more than €100 Million of island investments in clean technologies by 2023.

- All the EU Member States have been asked to submit their **energy and climate plans (NECP)** before the end of 2019 and are now required to develop national long-term strategies ensuring consistency with their NECPs.
- **European Green Deal** is the new EC initiative for Europe becoming the world's first climate-neutral continent by 2050, with an ambitious package of measures that should enable European citizens and businesses to benefit from sustainable green transition.
- **Innovation Fund** is a new programme under development that will follow up the NER 300 programme for supporting first-of-a-kind commercial-scale renewable energy projects. A first call is expected to be launched in 2020.
- **InnovFin Energy Demo Projects (EDP)** launched by the European Investment Bank (EIB) together with the European Commission provides support in the form of loans for first-of-a kind projects. Waveroller is the only wave energy project benefiting from this scheme.
- Access to testing infrastructures and centres and to research facilities across Europe have been supported by H2020 and European Regional Development Fund (ERDF). Examples of these projects are Marinet2, Marinerg-i, Foresea and Bluegift facilitating real sea environments and proving that power can be economically generated from the ocean.

France

- **In 2019, ADEME** launched several calls from system components and prototypes to ocean energy pilot farms with an estimated cumulative budget of €68 million. Further, two notable new projects were co-funded by ADEME in 2019: a multi-energy system - P**hares project** - on the non-grid connected Ushant Island and an original salinity gradient energy converter for desalination plants, the **Sarbacanne project**.
- **France Energies Marines (FEM)** has secured a €4 million support from the Government over 2019 and 2020 for innovative research and development projects inducing around €10 million of leveraged financing.
- **WEAMEC** in the Pays de la Loire Region has cumulated awarded funding of €6 million since 2016 for projects dedicated to local academic teams in conjunction with industrial stakeholders.
- Interest remains in **OTEC**: on the Réunion Island tests have been running at the onshore OTEC prototype set up by Reunion Island University and Naval Energies. Also, in La Martinique, Naval Energies carried out biofouling tests in OTEC components, in collaboration with IFREMER.
- A major project in deep sea conversion - **Bois Rouge eco-technoport on Reunion Island** – is under development. It includes renewable electricity production using OTEC, air-conditioning, industrial cooling, aquaculture, desalinisation and bottling of drinking water, and production of cosmetics.
- France has several test centres fully equipped and grid connected where wave and tidal energy demonstration projects are being tested:
  - At the SEM-REV test site on the Atlantic coast the **Wavegem platform**, a hybrid (wave, solar) autonomous energy production designed by GEPS Techno has been tested;
  - At Paimpol-Bréhat in the Channel, a test site run by EDF, **OceanQuest** tidal turbine connected to the grid has already reached 6 months of continuous operation;
  - In the Etel river estuary in Brittany, the **Guinard Energy** turbine of 20 kW which is integrated into a hybrid system with PV panels and battery storage, has been grid connected.
  - **Sabella** project has been progressing on Ushant Island, not connected to the mainland grid.
- Other wave and tidal projects under development include:
  - **SBM Offshore** planning to test their wave energy technology offshore the port of Monaco;
  - **Hydroquest Ocean** planning a 10 MW pilot farm in the Alderney Race, Normandy.

Germany

- From January 2020, Germany will assume the presidency of the **North Seas Energy Cooperation**, which consists of ten European countries and the European Commission. They are all working together to develop offshore wind energy and the grid infrastructure at sea.
- 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.
- **SCHOTTEL HYDRO** with its partner **Sustainable Marine Energy (SME)** are continuing the sea trials of the "PLAT-I 4.63" prototype at Grand Passage in the Bay of Fundy, Canada, with plans for progressing to a new "PLAT-I 6.40" platform to be equipped with six tidal turbines rated at 420 kW in total. SCHOTTEL HYDRO is currently conducting a research project called "Optimization of a Floating Turbine System for Harnessing Tidal Energy" with a consortium of German partners for the development of a next generation power take-off system.

- **NEMOS** has successfully started testing its recent wave energy converter prototype in Ostend, Belgium, and is currently testing a scaled model of a multi-body wave energy device at the Development Centre for Ship Technology and Transport Systems in Germany.
- **SINN Power** has upgraded the two wave energy devices installed at a breakwater at the port of Heraklion, Greece and further deployed two additional fourth generation devices in September 2019.
- Other German suppliers, certification companies and consultants continue contributing to the technology and project development in the sector.

India

- The Indian Government approved the construction of a new **OTEC powered desalination plant** of 100 m^3/day capacity in Kavaratti, Lakshadweep Islands, and in 2019 launched the request for proposals for its design and implementation.
- The **OWC wave powered navigational buoy** for use in ports has been continuously operating for several months in the navigational channel off Kamarajar Port, Chennai. A technology transfer agreement to commercialise this technology was signed by three companies. Further, 4 buoys will be fabricated and deployed on Andaman & Nicobar (A&N) Islands funded by A&N Administration.
- In March 2019, NIOT organized the *International Conference on Technologies for Renewable Energy and Water* (INDACON-2019), with joint collaboration from Indian Desalination Association (InDA) and IEEE-Oceanic Engineering Society.

Ireland

- Ireland launched in 2019 the **Climate Action Plan** outlining over 150 actions to address climate disruption and chart a course towards ambitious decarbonisation targets; three actions are specifically relevant to the development of offshore renewables.
- The Sustainable Energy Authority of Ireland (SEAI) has supported ocean energy research and development with over €20 million funding provided to Irish SME's to develop their technologies. Since the support began in 2003, SEAI has funded 125 projects.
- Two European funded projects led by SEAI - OPIN and OceanSET – started in 2019 and will significantly contribute towards the wave and tidal sector progress. **OceanSET** will support the Implementation of the European Strategic Energy Technology Plan (SET Plan) for Ocean Energy. **OPIN** project (Ocean Power Innovation Network) aims to design, test and deliver an innovation model to build cross-sectoral collaboration, to accelerate growth of the ocean energy sector and its supply chains.
- The Irish wave energy developer, **Ocean Energy Ltd**, greatly progressed in 2019, with support from Irish and US public funding for the construction of its OE Buoy 500 kW machine that was transported in 2019 from Vigor ship yards in Oregon, USA to the US Navy WETS facility, in Hawaii, and it is anticipated that will be tested for one year.
- The Irish tidal current energy developer, **DesignPro** was funded €1.9 million from EU's Horizon 2020 SME Instrument Programme to develop and commercialise small-scale turbines; the company has deployed a 25 kW turbine at the SEENEOH test site in Bordeaux, France.
- **Smartbay** test site in Galway received in February the WASP (Wave Power Activated Sensor) buoy deployed by the Centre for Renewable Energy at Dundalk IT (CREDIT).
- The annual **Ocean Energy Europe Conference and Exhibition**, one of the most important events on Europe's ocean energy calendar took place in 2019 in Dublin, Ireland. The event was attended by over 400 people.
- The **Ocean Energy Ireland Portal** acts as 'one stop shop' to guide developers through the supports available in Ireland for the marine renewable energy sector.

Italy

- In Italy there is an increasing interest in the exploitation of wave and tidal energy converters. In particular, wave energy converters integrated into conventional breakwaters have gained more and more interest among the port managers.
- The Mediterranea University of Reggio Calabria has been developing **REWEC3** (REsonant Wave Energy Converter), of the Oscillating Water Column; the device has already been installed in the port of Civitavecchia and soon it will be built in the Port of Salerno.
- Polytechnic of Turin has been developing **ISWEC** (Inertial Sea Wave Energy Converter) suitable for the Mediterranean and in March 2019 has put into operation a pilot project of 50 kW in the Adriatic Sea off the coast of Ravenna. This unit is part of a hybrid system that integrates photovoltaics and storage.
- In October 2019, four companies - **Fincantieri, Cassa depositi e Prestiti, ENI and Terna** - joined forces to develop an industrial wave energy plant based on the ISWEC system. The first ISWEC industrial installation near ENI's Prezioso platform in the Strait of Sicily is expected to be launched in the second half of 2020.
- **H-WEP 1** is a wave energy device first deployed off the coast of Marina di Pisa (Tuscany) by 40South Energy since September 2018 and it is operated and managed by Enel Green Power.

- **KOBOLD turbine** built by Ponte di Archimede installed in the Strait of Messina in the year 2000 is still in operation and connected to the grid with a nominal power of 30 kW.
- The Aircaft Design & AeroflightDynamics Group (ADAG) of the University of Naples "Federico II", in cooperation with SeaPower Scrl, has designed **GEM**, the Ocean's Kite planned to be installed in the Strait of Messina.
- The North American company **Ocean Power Technologies (OPT)** continues to develop the PowerBuoy device which has been deployed in the Adriatic Sea since November 2018 by the oil and gas company Eni aiming to demonstrate the suitability of wave energy technologies in the oil and gas operations. The OPT PowerBuoy will be used to advance Eni's research and development of integrated subsea technology systems to allow future applications for remotely controlled field developments powered by wave energy, as well as environmental monitoring and offshore asset inspection using autonomous underwater vehicles.
- In September 2019 Naples hosted the European Wave and Tidal Energy Conference (EWTEC), the biennial international conference dedicated to renewable technologies from marine sources, with Enel Green Power as the main sponsor of this event.

Mexico

- The Mexican Government is currently preparing a carbon market, aiming to create mechanisms to benefit low carbon initiatives.
- Main national priorities in the country for ocean energy are training and capacity building, development of the regulatory frameworks and development of innovative technologies. The approximate budget of the CEMIE-Oceano for 2019 was around €2 million.
- In line with the programme for the implementation of the Technological Roadmaps for ocean energies published by the Ministry of Energy, a theoretical assessment of wave, current, salinity gradient and thermal gradient energy resources in Mexico has been conducted by CEMIE-Oceano.
- **CEMIE-Oceano** continues with an increased number of activities in the ocean energy field: the Wave Energy group has been working on the development and laboratory testing of five wave energy converters; the Tidal and Current group is carrying out in situ measurements for assessing the feasibility of tidal current energy in some regions; the Salinity Gradient group has been collecting data from representative coastal systems in México and performing laboratory tests with scale prototypes; the Thermal Gradient group continues working in the compilation of an OTEC atlas and it is further in the final phase of the construction of a prototype.
- CEMIE-Oceano continues to explore two natural testing sites: Ensenada, Baja California, and Cozumel Canal, Quintana Roo, respectively for wave and tidal current projects.
- Laboratory installations for testing wave energy devices in Mexico have been improved with the construction of a wave tank at the University of Campeche.

Netherlands

- The **marine spatial planning** in the Netherlands has dedicated areas for offshore wind (3500 MW). A spatial analysis of the potential of the North Sea with a view to 2050 has been made, regarding 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 further techniques are developed to fit the Dutch situation, with relatively low tidal heads and speeds.
- DMEC, the Dutch Marine Energy Centre, has been an active player on ocean energy in the country, since 2016, focusing on the cooperation between business and universities.
- During 2019 a new test site was developed, the **Tidal Technology Centre Grevelingendam** expected to be completed in 2020. This test facility offers three different sized channels for low head tidal turbines.
- In 2019, **SeaQurrent** operated and tested their TidalKite Power Plant, in the Wadden Sea, appropriated for low velocity tidal and ocean currents. The company is planning a first commercial grid-connected demonstration project in the Wadden Sea, north of the Netherlands.
- **Redstack** continues their development with the Reverse Electro Dialysis (RED) technology, a salinity gradient power technology that makes use of membranes. After testing the technology in the pilot facility on the Afsluitdijk, Redstack now aims at a first demonstration plant at Katwijk (near The Hague), where the salinity gradient is optimal.
- Since 2015, **Tocardo** has been operating and testing their 1.25 MW tidal power plant in the Eastern Scheldt and has been planning a 2 MW successor, despite their declaration of bankrupt in October 2019.
- Plans continue for two OTEC projects: the OTEC Pilot Curacao (500 KW) and OTEC Pilot project at Martinique.
- On 7-9 October the Offshore Energy Exhibition & Conference (OEEC) was organized in cooperation with the Dutch Marine Energy Centre (DMEC) in Amsterdam. This event is unique in bringing together the oil & gas, offshore wind and marine energy industry.

Norway

- **Runde Environmental Centre (REC)**, located on Runde Island on the Norwegian west coast for wave energy testing, has a 3 km/0.5 MW underwater cable. REC facilitates preparations, licensing, deployment and monitoring of wave energy devices, including other sub-sea tests for anti-corrosion and anti-fouling.
- **Innovation Norway** runs a programme supporting prototypes within "Environment friendly technology" and ocean energy is included in this definition; projects are supported with up to 45% of eligible costs. Further, the research programme called ENERGIX run by the **Research Council of Norway** supports R&D applied to renewable energy technologies.

Portugal

- In 2019, the National Maritime Spatial Plan (**PSOEM**) was approved establishing the licensing regime for private use of the maritime space including marine renewable energies.
- Portugal Ventures launched the **Call Blue Economy** in partnership with the national funding called "Fundo Azul", with the purpose of supporting new business areas or new sectors of the sea economy, including ocean energy.
- WavEC has been involved in a significant number of R&D projects related to wave energy technologies and related components mainly funded by the European Commission. WavEC coordinates two national funded projects: **JUMP**, aiming to collect acoustic data from marine energy devices and promote the debate with stakeholders and **BLUECAO** focused on the development of an offshore platform concept for offshore aquaculture farms powered by wave energy.
- Within the European funded project OPERA (H2020), the wave energy group of IST jointly with the Portuguese company Kymaner, has designed a prototype of a **biradial self-rectifying air turbine** with a new type of fixed guide vanes and a fast valve. The turbine-generator prototype supplied by Kymaner has been installed on the MARMOK-A-5 spar-buoy OWC of the Spanish company Oceantec/IDOM operational at the BiMEP test site between October 2018 and May 2019.
- A wave-powered oceanographic buoy, based on the **OWC spar-buoy concept** is under development by IST/IDMEC to be deployed off the island of Faial, in the Azores Archipelago, in 2020.
- Other active groups developing projects in Portugal on wave energy technologies exist at Instituto Superior Técnico (IST), University of Porto (UPorto) and University of Algarve.
- **AW Energy's** First-of-a-Kind (FOAK) WaveRoller of 300 kW installed capacity, was deployed in October 2019 along the coast of Peniche. AW-Energy is also running a European funded project (Megaroller) for development of a 1 MW Power Take-Off unit, involving two Portuguese partners.
- The Swedish wave energy developer, **Corpower**, has been planning its next development at Aguçadoura test site in northern Portugal, which already has an onshore substation and a land cable in place. The anchors and mooring system are planned to be installed during the summer of 2020.
- In December 2019, WavEC organised its Annual Seminar 2019 on the challenges and opportunities in the offshore renewable and aquaculture industry in collaboration with the Norwegian Embassy in Portugal.

Republic of Korea

- National funding for ocean energy R&D projects, including demonstration projects, in 2019 amounts to USD 16.2 million.
- Two open-sea test sites for wave energy converters and for tidal energy converters are being developed. The **KRISO-Wave Energy Test Site (KRISO-WETS)** will open in July 2020, and the **Korea Tidal Current Energy Center (KTEC)**, established by KIOST, has been under development since 2017 and is expected to be completed by December 2022. The offshore cables were installed in KRISO-WETS during 2019;
- **Korea Research Institute of Ships and Ocean Engineering (KRISO)** is developing small wave energy converters of the oscillating water column (OWC) type, combined with breakwaters and energy storage systems, to provide electricity to remote off-grid islands. In 2019, prototypes of energy conversion modules were manufactured as part of a wave power demonstration plant.
- KRISO is also in charge of developing a **1 MW OTEC demonstration plant**. A short-term demonstration was completed in the East Sea in September 2019, and was followed by the construction of an on-land type plant in South Tarawa, Kiribati, in 2020-2021.
- An ongoing international cooperation project (2018-2020) between South Korea and China will exchange technology development and the utilization of ocean energy systems. As part of this project, two symposiums have been organised in 2019.
- The 7th International OTEC Symposium was held in Busan, South Korea, on 27-28 September and was hosted by KRISO and the Korean Society of Power System Engineering (KSPSE).

Singapore

- Over S$140 million has been allocated by the Singapore Government for research into clean energy

technologies and ocean energy has been identified as one of the prominent alternative energy specifically towards remote coastal regions and islands.

- The **Sentosa Tidal Test Site** officially launched in 2013 with governmental support aims to showcase tidal energy extraction as a feasible and sustainable energy generating technology in Singapore and to provide opportunities to develop local technologies. Recent developments at this test site include the deployments of tidal turbines supported in floating barges. Also, novel concepts such as floating solar systems and anti-biofouling coatings have been evaluated.
- A new **Deepwater Ocean Basin** was built by the Technology Centre for Offshore and Marine Singapore (TCOMS), which is a joint venture between the National University of Singapore (NUS) and the Agency for Science Technology and Research.
- **MAKO Tidal Turbines** has been using the ERI@N tidal site for its turbine demonstration project, in collaboration with Singapore industrial partners.
- The **Renewable Energy Integration Demonstrator-Singapore (REIDS)** continues to progress aiming to power Pulau Semakau, an island on the south of Singapore, through renewables, including ocean energy.
- The **Tropical Marine Energy Centre (TMEC)**, has been initiated by ERI@N, 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. Presently, an environmental impact assessment (EIA) for the test sites is being carried. Overall, the present project aims to meeting energy needs on remote islands.
- 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 attracts large number of tourists every year.
- Several initiatives on **floating solar** are under development in Singapore: Singapore's Economic Development Board (EDB) has issued a request for information to explore the feasibility of a 100 MW floating solar project.
- An **International Floating Solar Symposium** was organized in October 2019 as part of Asia Clean Energy Summit (ACES).

Spain

- During 2019, the Spanish Government continued working in the Energy and Climate National Integrated Plan 2021-2030. At a draft stage, it sets for **ocean energy targets** of 25 MW of installed capacity for 2025 and 50 MW for 2030.
- The **maritime space management plan** is under development with a first draft expected to go for public consultation in 2020.
- The **Basque Energy Agency (EVE)** launched a new call for its "Demonstration and validation of emerging marine renewable energy technologies" programme in 2019. As in previous calls, the programme has a budget of €2,5 million for a maximum of 3-year duration projects.
- The **DTOceanPlus** project, funded under the H2020 programme and coordinated by TECNALIA, reached its mid-term in October 2019. Under this project an integrated open-source suite of design tools to support the entire innovation and development process for ocean energy sub-systems, devices and arrays is being developed.
- **SEA-TITAN** project (2018-2021), funded under the H2020 programme and coordinated by WEDGE GLOBAL, continues making good progress, completing in 2019 the modelling and design of the new PTO modular unit.
- The **ELBE project** is part of the European Union DG GROWTH "Cluster Go International" programme. ELBE aims to contribute positioning Europe as a world technological and industrial leader in Blue Energy, with a focus on emerging areas such as floating offshore wind, wave and tidal energy. The alliance gathers five European clusters in Scotland, Belgium, Sweden and Denmark, under the co-ordination of the Basque Energy Cluster and foster to define a joint internationalisation strategy.
- During 2019, the third and fourth calls for transnational access to European offshore renewable energy test facilities were assessed within the MARINET2 project, a H2020 programme project, which brought to Spain new users to **HarshLab** and **Mutriku**.
- **Mutriku Wave Power Plant**, the first multi-turbine wave energy facility in the world, has been integrated in BiMEP infrastructure, being now a second facility of BiMEP. In the spring of 2019, the Irish company Waveram developed a test campaign taking advantage of MARINET2 funds.
- **HarshLab** is an advanced floating laboratory for the evaluation of standardized probes and components in an offshore environment developed by TECNALIA. It is installed at BIMEP since September 2018.
- The so-called **MARMOK-A-5** device developed by OCEANTEC (acquired by IDOM in September 2018) tested at Bimep test site was decommissioned in June 2019 after successful periods of testing.
- Other test campaigns were carried out at BiMEP in 2019 by the company **ZUNIBAL**, with its oceanographic buoy ANTEIA.
- The Galicia-based company **Magallanes Renovables** with its 1.7 MW power platform has been installed since February 2019 in Orkney. During the year 2019,

the company has been able to validate operations in real conditions.

- EVE, TECNALIA and BEC (Bilbao Exhibition Centre) organised the fourth edition of **Marine Energy Week** as part of a wider maritime event "World Maritime Week", in collaboration with the Basque Energy Cluster in February 2019.

Sweden

- In December 2019, the Swedish Agency for Marine and Water Management submitted a **marine spatial plan** proposal to the Swedish Government, which shall form part of the basis for municipality decisions regarding the most appropriate usage of a marine area, including ocean energy test sites.
- Swedish companies and universities were involved in several R&D projects during 2019, among which installation and maintenance methods of marine energy converters, the use of affordable and efficient radar technology to provide future wave information and investigation of elastic mooring systems for wave energy converters.
- Five strong research stakeholders - University of Gothenburg, Chalmers University of Technology, KTH Royal Institute of Technology, IVL Swedish Environmental Research Institute, and RISE Research Institutes of Sweden - together with support from Lysekil municipality, are now jointly building a new research and innovation environment for sustainable blue growth, the **Kristineberg Research and Innovation Center**.
- A number of Swedish developers achieved relevant milestones:
  - **Minesto** has been progressing with the technology called Deep Green; in 2019, a 500 kW turbine was installed off North Wales; the 2019 test programme in particular encompassed offshore testing with an upgraded system.
  - **Ocean Harvesting Technologies** (OHT) has been developing the novel 500 kW InfinityWEC wave energy converter since 2017. An R&D project was started in April 2019 carried out by OHT, Sigma Energy & Marine, NSK and Teraloop.
  - **Novige** has been developing a point absorber that uses a Pelton turbine to run a generator; in December 2019, a small-scale unit was deployed at a site outside Stockholm; after a period of tests, the unit will be prepared for wave tank testing in Plymouth.
  - **CorPower Ocean** continues its HiWave demonstration project that started in mid-2018 and will run until 2023. The HiWave-5 project aims at deploying three operational devices by 2023; Since 2019, CorPower is preparing the prototype certification of its first full scale 300 kW wave energy converter power to be tested in Portugal.
  - **Waves4Power** is one of the successful applicants that will be able to test its wave energy device at the European Marine Energy Centre (EMEC) in Orkney within the call launched in 2019 by the EU-funded Ocean DEMO project.

> With numerous projects in the water and thousands of MWh of electricity generation (including the world's largest tidal array MeyGen), 2019 was a growth year for the marine energy sector in the UK. The year saw numerous innovative cross-border collaborations, deployment of state-of-the-art projects and offshore tests being undertaken.

United Kingdom

- 2019 was a growth year for the marine energy sector in the UK with numerous innovative cross-border collaborations, deployment of state-of-the-art projects and offshore tests being undertaken.
- **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. In 2019, the programme awarded £9 million to eleven wave energy technology projects through various innovation projects and research activities.
- The **Welsh European Funding Office (WEFO)** in Wales also continues to contribute significantly to wave R&D with £30.4 million being allocated for wave energy development since 2014.
- In 2019, many tidal stream projects made significant progress towards commercialisation. By the end of 2019, SIMEC Atlantis' four-turbine 6 MW **MeyGen** project had clocked up over 23 GWh of generation.
- The **Nova Innovation** three-turbine 0.3 MW array continued to operate, with the turbines accumulating over 20,000 hours generating power to the grid (as of December 2019). The company has also been granted licence to deploy a 1.5 MW tidal array starting 2020 in the Bay of Fundy area of Nova Scotia.
- The 2 MW floating SR2000 device from **Orbital Marine Power** also achieved 3 GWh of generation over a year of

continuous deployment. In 2019, Orbital Marine Power commenced construction of their optimised production model, the 2 MW Orbital O2, for deployment at the European Marine Energy Centre (EMEC) in 2020.

- **Minesto** deployed their commercial scale low flow technology off the coast of Anglesey and have secured their first international orders for the Deep Green technology.
- The **Tidal Stream Industry Energiser** (TIGER) project was initiated in July 2019 planning to deploy up to 8 MW of new tidal capacity around the Channel region. Led by ORE Catapult, the TIGER project is an ambitious €46.8 million project running from July 2019 to June 2023.

United States of America

- In 2019, the U.S. Department of Energy (DOE) Water Power Technologies Office (WPTO) formally launched a new R&D initiative called **Powering the Blue Economy** and published in March the report, Powering the Blue Economy™: Exploring Opportunities for Marine Renewable Energy in Maritime Markets.
- In January 2019 WPTO awarded $25 million in research projects for next-generation marine energy devices.
- A new testing programme for marine energy technologies - TEAMER - was announced; it will be a three-year, $16 million programme supporting testing and research for marine energy technologies and will provide technology developers access to testing infrastructure.
- In June 2019, WPTO launched the **Waves to Water Prize**, a four-stage competition providing up to $2.5 million in cash prizes to demonstrate desalination systems; ten winners of the first stage of the competition have been announced in November 2019.
- In June 2019, seven small marine energy businesses were selected by WPTO through the Energy Department's **Small Business Innovation Research (SBIR)** programme in topics such as pumping and compression, microgrids in remote coastal communities, ocean energy storage, and critical mineral harvesting from seawater.
- **Marine Energy Collegiate Competition (MECC)** is a new initiative launched in 2019 by the WPTO, in which fifteen teams of students will explore innovative marine energy solutions to address power needs across the blue economy. Finalists will present their design during the International Conference on Ocean Energy in Washington, DC in May 2020.
- The **Marine and Hydrokinetic Graduate Student Research Program** was launched in October 2019, administered by WPTO and the Oak Ridge Institute for Science and Education (ORISE).
- In October 2019 WPTO announced grant selections for up to $24.9 million in funding to drive innovative, industry-led technology solutions to advance hydro and marine and hydrokinetics industries, some of the grant recipients include: C-Power (formerly Columbia Power Technologies, Inc.), CalWave Power Technologies, Inc., Stevens Institute of Technology, Ocean Renewable Power Company, ABB Inc., Purdue University, and IDOM, Inc.
- In November 2019 WPTO, in partnership with the National Oceanic and Atmospheric Administration (NOAA) Integrated Ocean Observing System (IOOS), launched the **Powering the Blue Economy: Ocean Observing Prize**. This competition will award up to $3 million in cash prizes to challenge competitors to develop novel ways of integrating marine energy systems with ocean observing platforms and technologies.
- A number of wave and tidal companies have achieved relevant milestones in 2019:
  - **Ocean Power Technologies** achieved 1-year of continuous operation of its PB3 PowerBuoy® wave energy converter of 3 kW in the Adriatic Sea.
  - **Ocean Energy** has towed its 500 kW Ocean Energy Buoy across the Pacific, in November 2019, to the testing site at the U.S. Navy's Wave Energy Test Site in Hawaii.
  - **Ocean Renewable Power Company** (ORPC) and the Igiugig Village in Alaska deployed a 35 kW submerged crossflow river current turbine system, the RivGen® Power System, into the Kvichak River. This village became the first U.S. tribal entity to receive a Federal Energy Regulatory Commission permit for a water-powered project not connected to a dam.
  - **C·Power** (formerly Columbia Power Technologies) completed the fabrication drawings for its utility-scale StingRAY H2 wave energy device, planned to be tested at the U.S. Navy's Wave Energy Test Site in Hawaii. Further, in 2019, C-Power initiated the design of small-scale units dedicated to ocean observation, commercial and defence sectors planned to be tested at the PacWave-North test facility of the Oregon.
  - **Verdant Power** continues developing their tidal current project at the East River near New York City and 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.
  - **Oscilla Power** has completed extensive testing at scale with its wave energy device called Triton and is now working towards a commercial scale system through a number of WPTO-funded programmes.
  - Both **AquaHarmonics** and **CalWave**, first and second-place winners of the 2016 Wave Energy Prize respectively, have been progressing and are aiming to deploy scaled systems in the coming years.

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.

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

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

IRELAND

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

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

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

SWEDEN

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

DENMARK

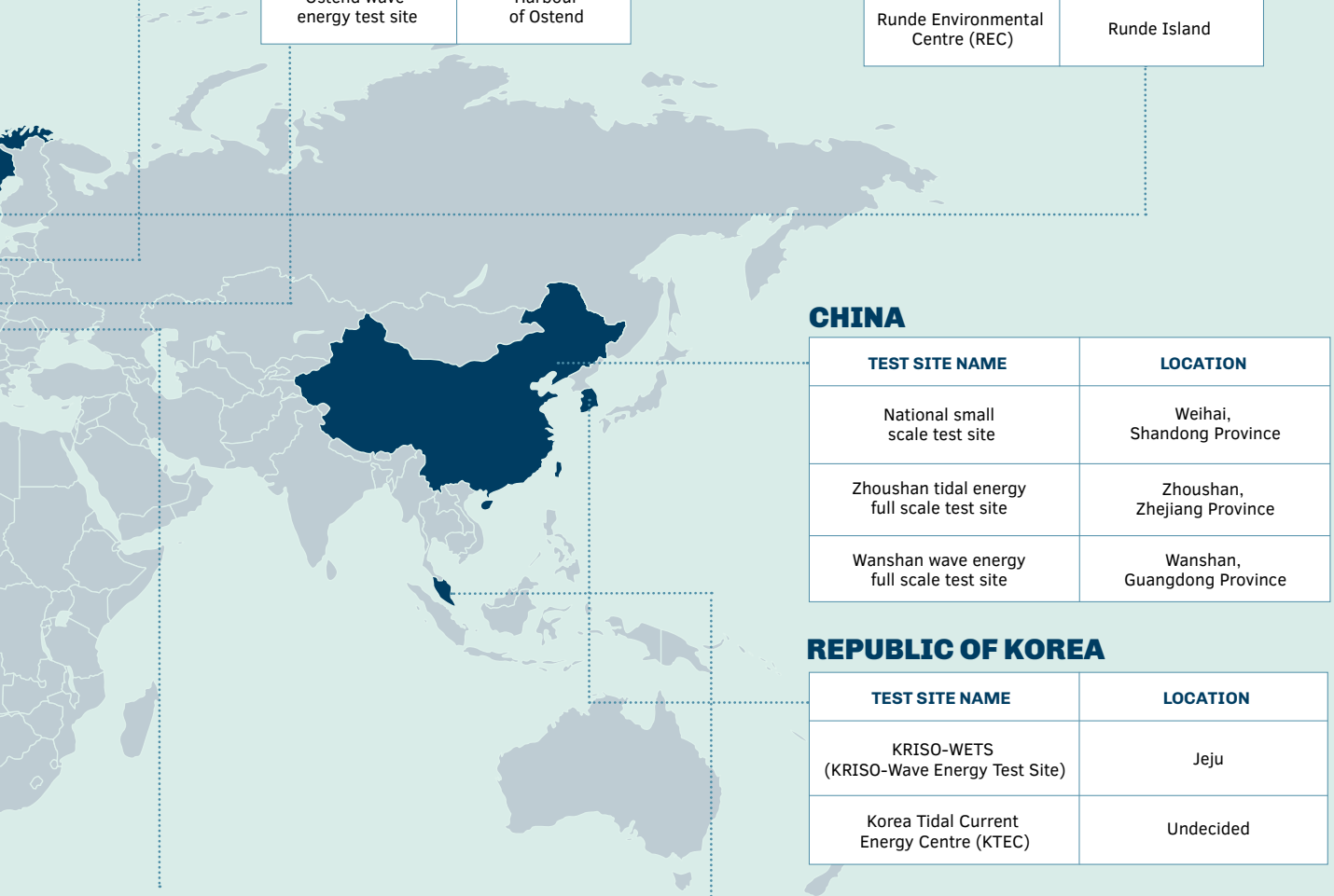
TEST SITE NAME	LOCATION
DanWEC	Hanstholm
DanWEC NB	Nissum Bredning

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
KRISO-WETS (KRISO-Wave Energy Test Site)	Jeju
Korea Tidal Current Energy Centre (KTEC)	Undecided

FRANCE

TEST SITE NAME	LOCATION
SEM-REV, wave and floating offshore wind test-site	Le Croisic
SEENEOH estuarine and ¼ 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

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 has also established a set of Organisational Values to its future actions:

Integrity: Any information provided can be relied upon.

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

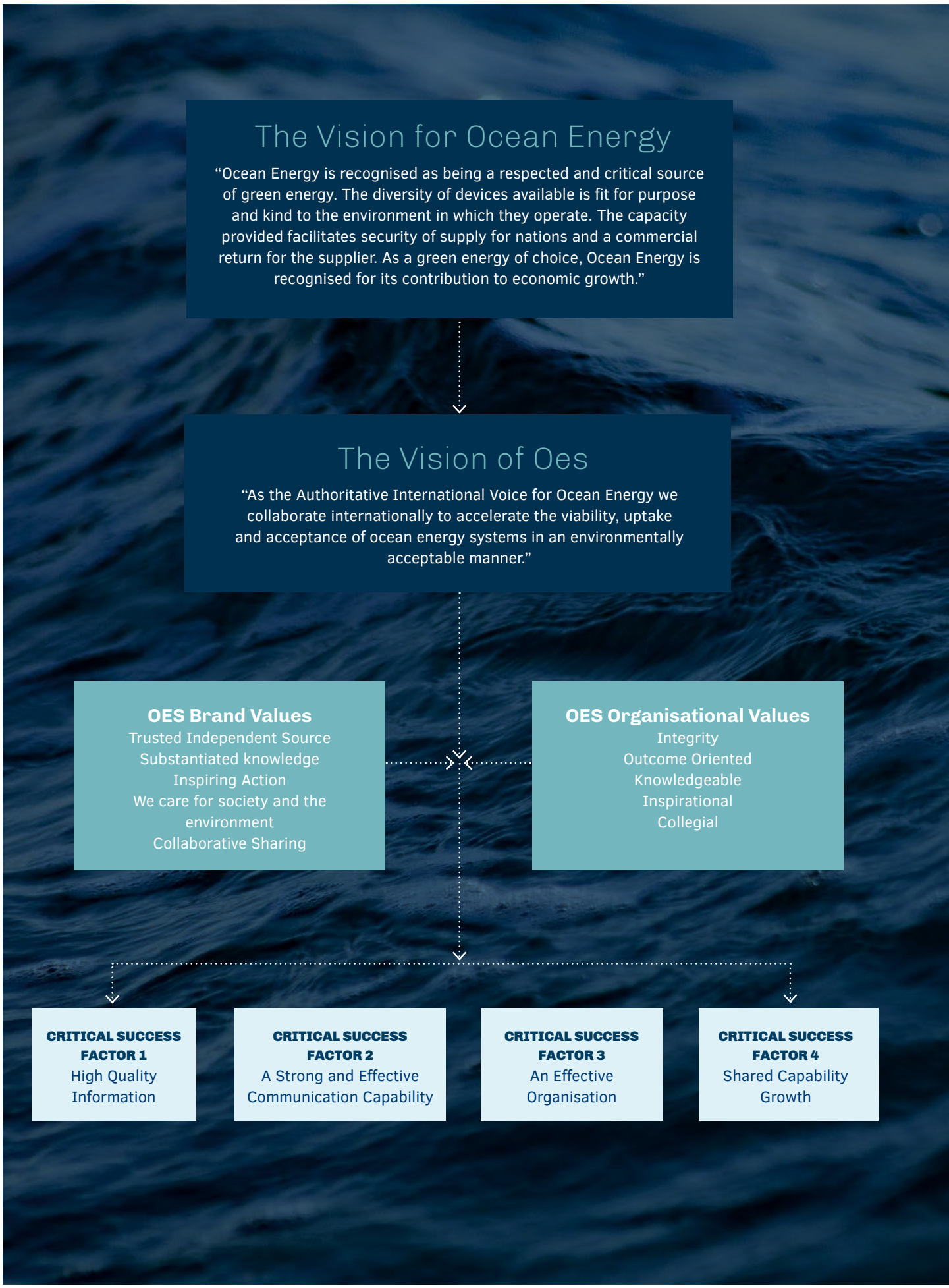
Knowledgeable: All information is based on fact and we strive to ensure that we always have the most relevant and up-to-date researched facts available.

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 influenced by the organisational values of OES and its brand values, the Strategic Plan for OES identified and prioritised four **Critical Success Factors**, for which an action plan has been prepared:

- High quality information
- A strong communication 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

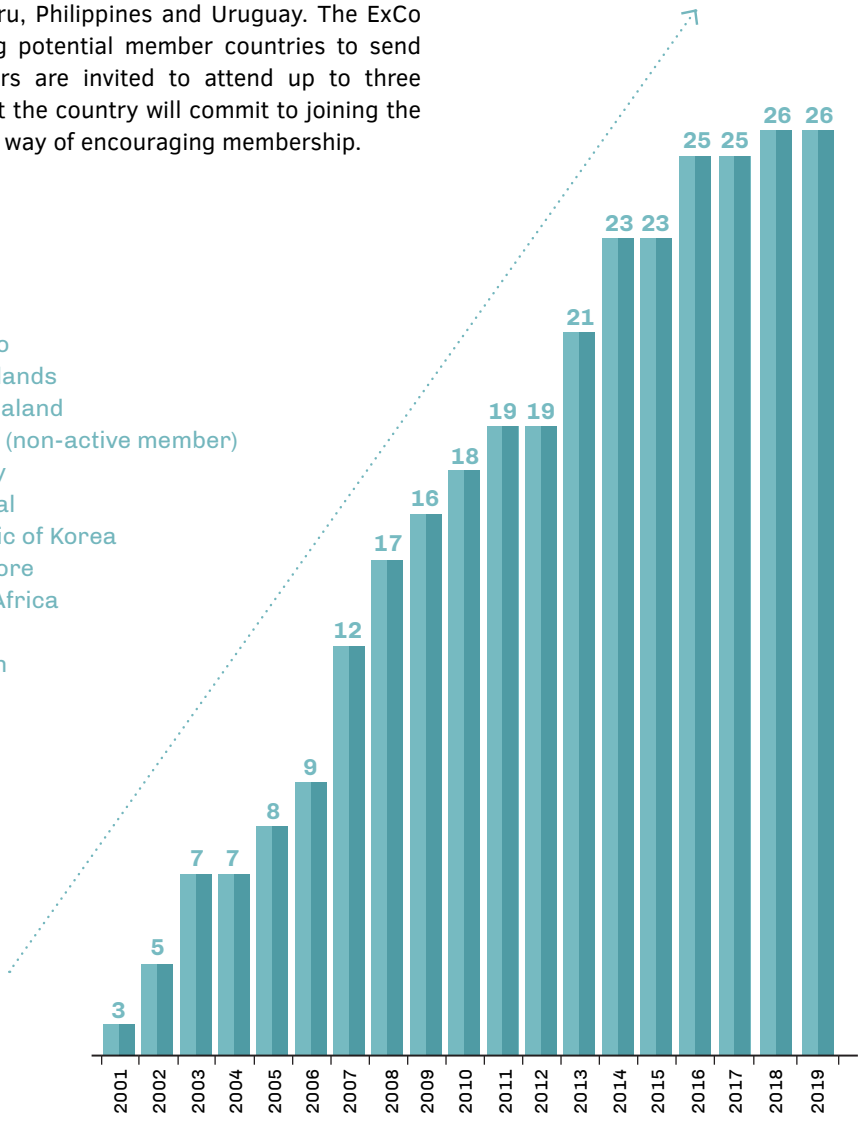
The Technology Collaboration Programme on Ocean Energy Systems (OES) was initiated by three countries in 2001 and has been growing steadily. As of December 2019, 24 Member Countries and the European Commission are active members of the OES.

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 to be an effective way of encouraging membership.

Member Countries

Australia
Belgium
Canada
China
Denmark
European Commission
France
Germany
India
Ireland
Italy
Japan
Mexico
Monaco
Netherlands
New Zealand
Nigeria (non-active member)
Norway
Portugal
Republic of Korea
Singapore
South Africa
Spain
Sweden
UK
USA

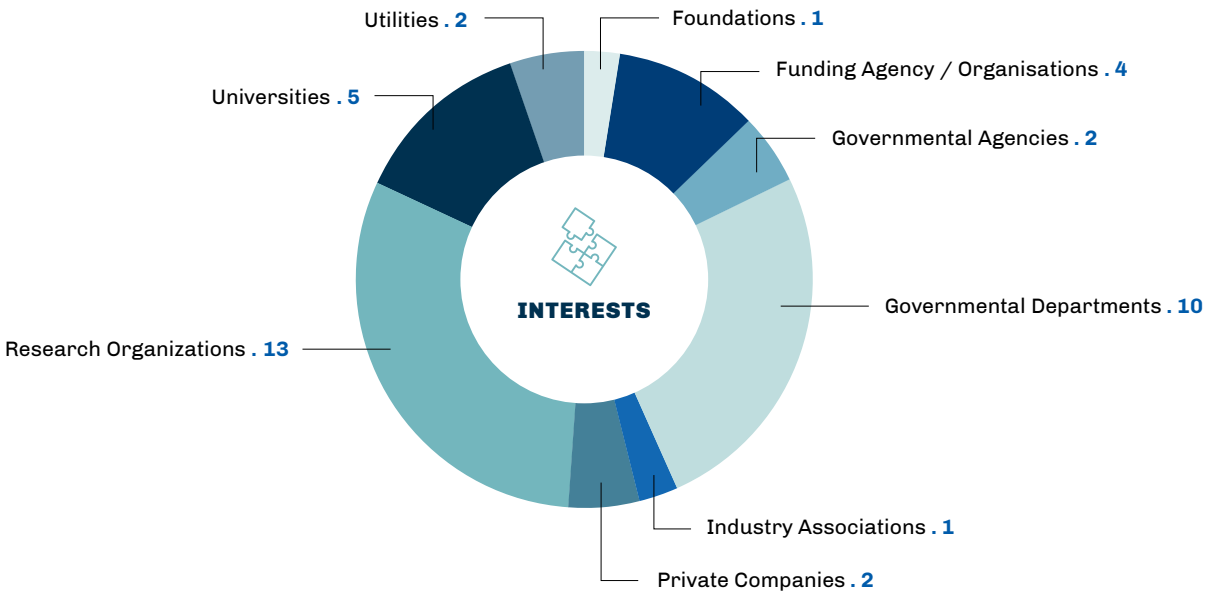


OES Membership Growth

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)

Diversified representation of interests in the ExCo



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 work programme.

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 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.

The 36th ExCo meeting took place in Riviera Maya, Mexico, on 26 – 27 March 2019, hosted by Cémie-Oceano, with 15 Delegates and 3 Observers (Chile, Panama and Uruguay). The 37th ExCo meeting was held in Dun Laoghaire, Dublin, Ireland, on 2 - 3 October with the participation of 18 Delegates and hosted by the Sustainable Energy Authority of Ireland.

In 2019, Henry Jeffrey (United Kingdom) served as Chair and Anne Dallman (USA) and Yann-Hervé De Roeck (France) served as Vice-Chairs.

In 2019, OES participated in the following IEA events:

- 3rd Universal Meeting of the Technology Collaboration Programmes, Paris, France, 18-19 June 2019;
- 76th IEA Renewable Energy Working Party Meeting (REWP 76), Helsinki, Finland, 10-11 September 2019;
- Global Ministerial Conference on System Integration of Renewables, Berlin, Germany, 1 October 2019.

36th Exco Meeting in Riviera Maya, Mexico (26 – 27 March 2019)

37th Exco Meeting in Dublin, Ireland (2 – 3 October 2019)

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 2019 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 Nº	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	Concluded
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	France	Active
New activities under discussion	Ocean Energy applications on Islands		
	Open Water Testing		
	Ocean Energy Policies		
	Time Value of Energy		
	Alternative Markets on Ocean Energy		

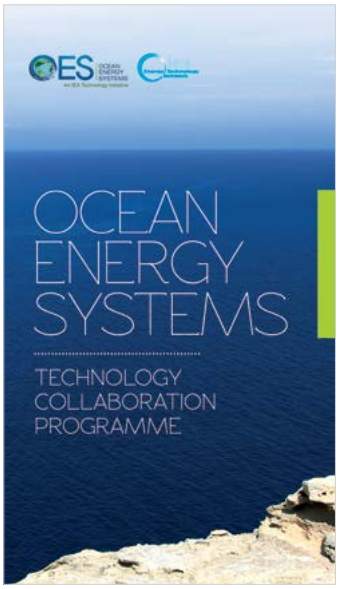
02

ACHIEVEMENTS IN 2019

Dissemination, Communication and International Collaboration

In 2019, the OES launched a new video promoting ocean energy and the role of OES to the general public.

The brochure Spotlight on Ocean Energy providing insights of 20 ocean energy projects and 5 policy initiatives on the OES Member Countries continued to be distributed in key events on ocean energy.



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

- **Launch of a new OES website** (www.ocean-energy-systems.org).
- **Launch of a new video promoting ocean energy**, available on the OES website.
- **Social Networks**: news is promoted through a LinkedIn group and a twitter account with more than 800 followers by the end of 2019.
- **Annual Report**, the flagship document of the OES and a marker for industry development. It includes detailed information from Member Countries.
- **Press Releases**: Three press releases were issued in 2019 announcing the launch of the Annual Report, the start of the jobs creation study and the launch of the new video.
- **Presence** of OES representatives in several events related to ocean energy. The table below lists the main events in 2019, 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 2019

Event	Partnership	Date	Represented by
All Energy Conference	Glasgow, UK	May 2019	Chairman
7th International OTEC Symposium	Busan, KOREA	September 2019	Delegates from China, Japan, Korea and India
European Ocean Energy Conference (OEE 2019)	Dublin, IRELAND	October 2019	Chairman
World Ocean Council (WOC) Sustainable Ocean Summit	Paris, FRANCE	November 2019	Chairman
Wave Energy Scotland Annual Conference	Edinburgh, UK	December 2019	Chairman

In 2019 the 7th International OTEC Symposium was held in Busan, Republic of Korea (27 – 28 September) hosted by KRISO and the Korean Society of Power System Engineering (KSPSE). During this event Dr Purnima, OES delegate, has been awarded with the 2019 Uehara Prize for the contribution to the ocean thermal energy conversion.

7th International OTEC Symposium, Busan, Republic of Korea.
Dr Purnima, delegate from India, has been awarded for her contribution to the development of OTEC, delivered by Dr Ikegami, delegate from Japan.

Collaboration with IRENA

In 2019, OES collaborated with the International Renewable Energy Agency (IRENA) in the workshop "Unlocking the potential of ocean energy around the globe" held on 1-2 October in Dublin during the Ocean Energy Europe (OEE) Conference. The event featured sessions with national and regional representatives from all corners of the globe and key experts in ocean energy to discuss the latest progress in this field. It aimed at jointly identifying the most relevant gaps and future work in order to secure the industrial rollout of ocean energy projects in the near future. Furthermore, the sessions were intended to explore potential markets within the island context and present benefits and challenges, as well as past and present experiences regarding the deployment of ocean energy infrastructure across Small Islands Developing States (SIDS). OES presented the main findings of their 3 workshops organized under this topic in three different regions.

IRENA
International Renewable Energy Agency

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 the field of ocean energy through publication of research results and journal papers, making the results of the work available to a wider audience.

INTERNATIONAL NETWORK ON
INORE
OFFSHORE RENEWABLE ENERGY

Assessment of Environmental Effects and Monitoring Efforts

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 CONSULTANT
Andrea Copping, Pacific Northwest National Laboratory

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 first international programme engaged in bringing together information and practitioners on environmental effects of marine renewable energy (MRE) development.

Achievements

During 2019, OES-Environmental (OES-E) continued work on Phase 3 tasks:

- Continuing to populate metadata forms by compiling information from baseline data collection and monitoring efforts around deployed MRE devices and analogous marine technologies, as well as related research studies on environmental effects of marine renewable energy (MRE);
- Continuing to update and expand Tethys the publicly accessible knowledge management system, with papers, reports, and other media on environmental effects of MRE;
- Continuing outreach and engagement to the MRE community, with particular emphasis on researchers, regulators, and MRE device developers; and
- Continuing work towards streamlining consenting processes to enable more efficient deployment of MRE devices and arrays.

Fifteen nations participated in phase 3 of OES-E: Australia, Canada, China, Denmark, France, India, Ireland, Japan, Norway, Portugal, South Africa, Spain, Sweden, the United Kingdom, and the United States. The US continued to lead the initiative, with the Department of Energy (DOE) serving as the Operating Agent. As one of the DOE's national laboratories, Pacific Northwest National Laboratory (PNNL) implemented the project.

Meetings with OES-Environmental analysts

PNNL continued to organize and lead meetings approximately every 2-3 months with the OES-E country analysts to coordinate cooperative work. Starting in 2019, each OES-E analyst has been formally presenting MRE-related information about his or her country as well as regional interactions among nations, as part of the regular meetings. One to two countries share their presentations at each meeting. Also in 2019, PNNL coordinated one-on-one meetings with each country analyst to better determine the contributions of each nation and to ensure that the analysts are receiving the support they need. In addition, when possible, in person meetings with several analysts were held, at conferences such as EWTEC. Key points of discussion and cooperative work this year focused on the organization and preparation of the 2020 State of the Science report, as well as participation in workshops in Europe and other nations. This work was carried out with frequent email and telephone exchanges, in addition to the regular online meetings. As part of their work with OES-E, each nation's analysts shared information within their countries, including introducing

Tethys, gathering content for Tethys, and providing contacts with organizations in their countries to identify relevant monitoring, data collection, research funding, and implementation activities. The OES-E analysts continued to engage their nation's regulators through a survey to determine regulator understanding and information needs, and to share progress in the risk retirement process. The analysts also reach out to colleagues in their respective fields to initiate investigations into key areas that will assist the establishment of the MRE industry.

Metadata

In 2019 OES-E continued to collect and update information on new wave and tidal projects as well as ongoing research studies, stored as metadata forms on Tethys. Existing metadata forms are updated by working with the country analysts, developers, and researchers. The metadata collection form was updated to streamline the process and to standardize data for the purpose of display in the Monitoring Datasets Discoverability Matrix (a key portion of the risk retirement process), which is scheduled for release in early 2020.

Dissemination of information on environmental effects

Ongoing work to collect, curate, and make accessible existing information on MRE environmental effects for Tethys continues to expand the platform and reach ever larger audiences. There are currently 5,190 documents that address environmental effects of MRE available on Tethys. A biweekly electronic newsletter, Tethys Blast, is sent to the broad OES-E community of more than 1,790 individuals. In 2019, Tethys' social media presence was expanded with the addition of an Instagram account. More frequent posts and a strategy for reaching more users was implemented and used extensively to promote OES-E events and products. Specifically, from 2018: Facebook user engagement increased more than six times; Twitter engagements increased over eight times; and from April 2019 (when it was launched) to December 2019 Instagram gained over 100 followers.

Conferences

In September 2019, OES-E partnered with the European Wave and Tidal Energy Conference (EWTEC) held in Napoli, Italy to increase the environmental focus of the conference. A paper on the OES-E risk retirement process was presented by PNNL staff.

OES-E staff (PNNL) presented a poster at the US Marine Energy Technology Symposium on Tethys and risk retirement in May 2019, and a paper on risk retirement at the IEEE-MTS Oceans '19 conference in Seattle WA in October 2019.

Workshops

OES-E hosted several workshops and webinars in 2019, bringing together experts to further understanding of key interactions and to work towards consensus on how research and monitoring information can help inform consenting processes and accelerate depoyments for the MRE industry:

- A workshop held in conjunction with EWTEC in September 2019 focused on the risk retirement evidence base for underwater noise and electromagnetic fields (EMF) associated with MRE devices;
- Also in September, OES-E hosted a workshop at the Ocean Renewable Energy Conference in Portland OR, USA on risk retirement of underwater noise; and
- A workshop was held by OES-E in Sydney Australia in December 2019 that featured an update on the state of knowledge around environmental effects of MRE, as well as an expert assessment of risk retirement for underwater noise and EMF.

State of the Science

Throughout 2019, planning, preparation, and writing the 2020 State of the Science Report has been the major focus of OES-E. The report will be an update of the 2016 State of the Science; in addition new aspects of the report will provide discussion of technologies for measuring environmental effects in difficult oceanographic conditions around MRE devices, and strategies for streamlining consenting and management of MRE projects, including risk retirement.

Regulator outreach and engagement

In 2019, the process of surveying and analyzing results of a survey to regulators continued, with the results gathered and analyzed for five additional countries: the UK, France, Sweden, Spain, Ireland (the US survey was completed in 2018). As the surveys are completed for more OES-E nations, a meta-analysis will be completed and the results shared broadly. These surveys help OES-E guide the development of strategies, including data transferability and risk retirement, to streamline consenting processes.

Data Transferability and Risk Retirement

During 2019, the process of data transferability (first developed and tested in 2018) was further refined and integrated into an overall strategy called risk retirement. Through risk retirement, OES-E is developing an integrated and dynamic process for gathering evidence for stressors of concern for MRE development (such as collision risk, underwater noise, EMF, habitat changes) and evaluating that evidence with the help of subject matter experts, to determine if that risk can be "retired" for small number of devices. In this context, risk retirement means that each stressor interaction with the marine environment may not need to be investigated at every project, but rather appropriate data from already consented projects, analogous industries, and research studies can inform the consenting process. The risk retirement pathway was developed and tested in 2019, and the first interactions with experts to evaluate the evidence base took place at targeted workshops. This process will continue to be a focus of OES-E in 2020.

Cost of Energy Assessment for Wave, Tidal and OTEC at an International Level

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

Objectives

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.

The study done in 2015 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.

Methodology

Based on the previous study on costs and after an initial review of the cost model and cost driver analysis, a proper questionnaire was developed to collect detailed information from OE technologies. Tidal, Wave, OTEC, Salinity, HVAC technology developers have been contacted but only feedback from tidal and wave energy developers has been obtained.

Representative baseline projects have been defined with regards to data collected directly from developers. The baseline projects consider aspects such as technology type, position in the water column, rated capacity, etc.

A reverse LCOE calculation was carried out with the aim of defining CAPEX and OPEX objectives for each of the abovementioned baseline projects. A cost reduction assessment and comparison were carried out using representative baseline project costs and impact of different cost reduction pathways was investigated.

Main Conclusions

The study has shown that both wave and tidal energy, based on the collected baseline cases and with further successful development, will be able to reach the cost targets defined in the European Strategic Energy Technology Plan, where €150-100/MWh is projected by 2025-2030 for tidal and €150-100/MWh for wave by 2030-2035.

To achieve continued and successful development of ocean energy projects, investments in continued basic R&D, as well as continued development of test and pilot projects internationally, are required. The exchange of information and international co-operation under OES will be able to facilitate the dissemination of results, which will gradually help identify the best and most cost-effective solutions for the different ocean energy market segments.

Collection of information from technology developers and project promoters by public bodies that support ocean energy R&D will be critical to ensure a successful deployment of the sector.

The access to actual data from projects should be used to make progress on 5 aspects: learning curves, better understanding of ocean energy markets, jurisdictional programmes, synergies with other industries and integration with existing infrastructure.

Performance Metrics International Framework for Ocean Energy

COORDINATOR

Led by the European Commission and delivered by Wave Energy Scotland (WES) and the United States Department of Energy (DOE) with contributions from the OES Executive Committee.

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.

Objectives

This Task is part of an ongoing collaboration, which is working to gain international consensus on a Technology Evaluation Framework to be used in ocean energy technology development programmes to objectively measure key, targeted areas and facilitate decision-making.

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

During 2019 a report has been prepared discussing the benefits of common evaluation approaches in the ocean energy sector and the use of common language to help build consensus. It considers how the Evaluation Criteria and, more commonly, the Evaluation Process changes throughout the technology development process. The technology development process has been split into three parts, which are closely associated with the Technology Readiness Level scale:

- Early-stage - Low level of detail – represents technology before any detailed sub-system, device, or array numerical modelling;
- Mid-stage – Medium level of detail – represents technology measured by numerical modelling or tank testing;
- Late stage – High level of detail – represents technology measured by open water testing at specified sites.

A technology and its application can be assessed from different perspectives: system effectiveness, process efficiency, technology performance, cost effectiveness and commercial attractiveness. These perspectives can be broken down into various Evaluation Areas. These Evaluation Areas are categorised as measures of "Technology Performance" or "Process Efficiency", which can be combined into an evaluation of "System Effectiveness".

For each Evaluation Area, a set of Evaluation Criteria for Early, Mid and Late stage in the technology development process has been developed. A first report intended to be a living document is expected to be soon released and planned to be updated as further Evaluation Areas and details of Evaluation Process and implementation approach are added.

Ocean Energy Jobs Creation: Methodological Study and First Global Assessment

COORDINATOR
Yann-Hervé De Roeck, France Energies Marines

PARTNERS
LOC Consortium, comprising LOC Renewables (including INNOSEA)
Fraser of Allander Institute from the University of Strathclyde

Objectives

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.

This project aims at delivering a validated methodology for job assessment in the ocean energy sector and building up from the existing know-how developed on other renewable energies and other maritime sectors.

Achivements

In 2019, a state of the art of socio-economic methodologies used to assess the number of jobs created or maintained with the commercial deployment of Ocean Energy Systems has been prepared. The identification of economic activities related to Ocean Energy Systems is complex. In addition to capturing the existing economic contribution of renewable energy activities, there is also interest in quantifying the future impacts. Projections or forecasts are widely undertaken and used to inform policy decisions, so their accuracy is important.

There are different approaches used in the calculation of projected impacts, and so it is critical to review existing approaches before producing further quantitative estimates. It should be noted that the methodology developed will provide a result which relies on the approach used. Different methods would be likely to provide alternative results, which is why it is important that the choice of method is the most robust, transparent for users, and that policymakers and analysts are jointly aware of its limitations. From this, decisions on ocean energy can be informed by the most robust evidence base.

Wave Energy Converters Modelling Verification and Validation

COORDINATOR
Kim Nielsen, Ramboll, Denmark

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

Experimental OWC with a 2.5 meter wide opening tested at a water depth of 3.2 meter

Objectives

This project focuses on numerical modelling of wave energy converters, to verify and validate the design and power production calculations, with the following the long-term goals:

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

Achivements

The first test case was a very simple test case simulating the heave decay of a sphere in still water from an initial offset. This was followed by simulations of the sphere in regular and irregular waves and an imposed linear damping. The numerical results from the many partners were compared, and results were discussed and published at EWTEC 2017 and presented at the 3rd International Conference on Renewable Energies Offshore in October 2018 in Lisbon. During 2018, the team investigated how existing experimental test data from the US Navy MASK basin for a heaving buoy could be used to validate numerical results. A complete overview of the work done on heaving bodies was published in September 2019 in J. Mar. Sci. Eng; OES Wave Energy Modelling Task: Modelling, Verification and Validation of Wave Energy (see: https://www.mdpi.com/2077-1312/7/11/379).

In January 2019, work on simulating the MASK Basin experiments was completed and presented at a webinar. The options for follow up tasks were discussed, and it was proposed to simulate an Oscillating Water Column (OWC) system. Two sets of existing OWC data were presented and discussed 1) data from a small 1:50 scale OWC model which had been tested at DTU in Denmark and 2) data from a larger 1:4 scale OWC model tested at KRISO in Korea. The choice was made to use the KRISO experimental data.

A simulation plan of the “KRISO test case” was presented in May. It was agreed that the CFD model team should focus only on a few wave cases, while the group using linear or weakly nonlinear models would simulate all the tests cases. KRISO uploaded the experimental data to the NREL share point during the summer 2019.

NREL presented their simulation results at the 3rd webinar in September and WAMIT data was supplied by DTU for all to use. The numerical results compared relatively well, but discrepancy was noted, and it was decided to meet face to face in Amsterdam at the end of November 2019. At this meeting the results from

both linear and CFD models were presented and the differences between simulated and experimental results were discussed. It was decided to incorporate the effect of air compressibility in the OWC to investigate which impact this would have on the simulation results. At the workshop also a set of dedicated experimental sphere decay tests from AAU was presented, with the proposal to use these data to compare with the initial theoretical results. The workshop was supported by the OES and the WECANET.

Countries and institutions present in the webinars on numerical modelling for wave energy in 2019

Country	Organisation	Webinar Jan 2019	Webinar May 2019	Webinar Sep 2019	Workshop Nov 2019
Denmark	Ramboll	x	x	x	x
	Aalborg University	x	x	x	x
	Floating Power Plant	x		x	x
	DTU	x		x	x
France	INNOSEA	x			
Ireland	Maynooth University	x			
Japan	Saga University	x	x	x	
Portugal	Instituto Superior Técnico	x	x		
	CENTEC			x	
	WavEC				x
Republic of Korea	KRISO	x	x	x	x
Spain	Tecnalia	x	x	x	
Sweden	Chalmers University			x	x
	SSPA			x	
	RISE		x	x	x
UK	Wave Venture	x	x		
	Plymouth University	x	x	x	x
	EMEC				x
USA	NREL	x	x	x	x
	Sandia	x	x	x	
Hungary	Budapest University			x	x
Belgium	UGent			x	x
Canada	Dynamic Systems Analysis	x			
Netherlands	TU Delft				x

Tidal Energy Resource Modelling

COORDINATOR
Srikanth Narasimalu, Singapore

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

Objectives

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

As a great variety 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. **International Tidal Energy Working Group** was thus consequently formed as a part of Ocean Energy Systems (OES) and various international research teams are conducting extractable resource studies to share their results and methodology, and work towards creating a standard report for modelling in harnessing tidal energy. Thus, the main objective of this initiative is to develop a simulation guideline report of tidal energy resource modelling through a common case study with various factors along with code-to-code comparisons of various modelling strategies that exist in different parts of the models. It will also involve comparison of models with experimental data and also discussion on various assumptions made in models such as seabed friction effects, etc. These workshops are organised and hosted by Energy Research Institute @ NTU (ERI@N), Singapore, through teleconferencing on a half-yearly basis.

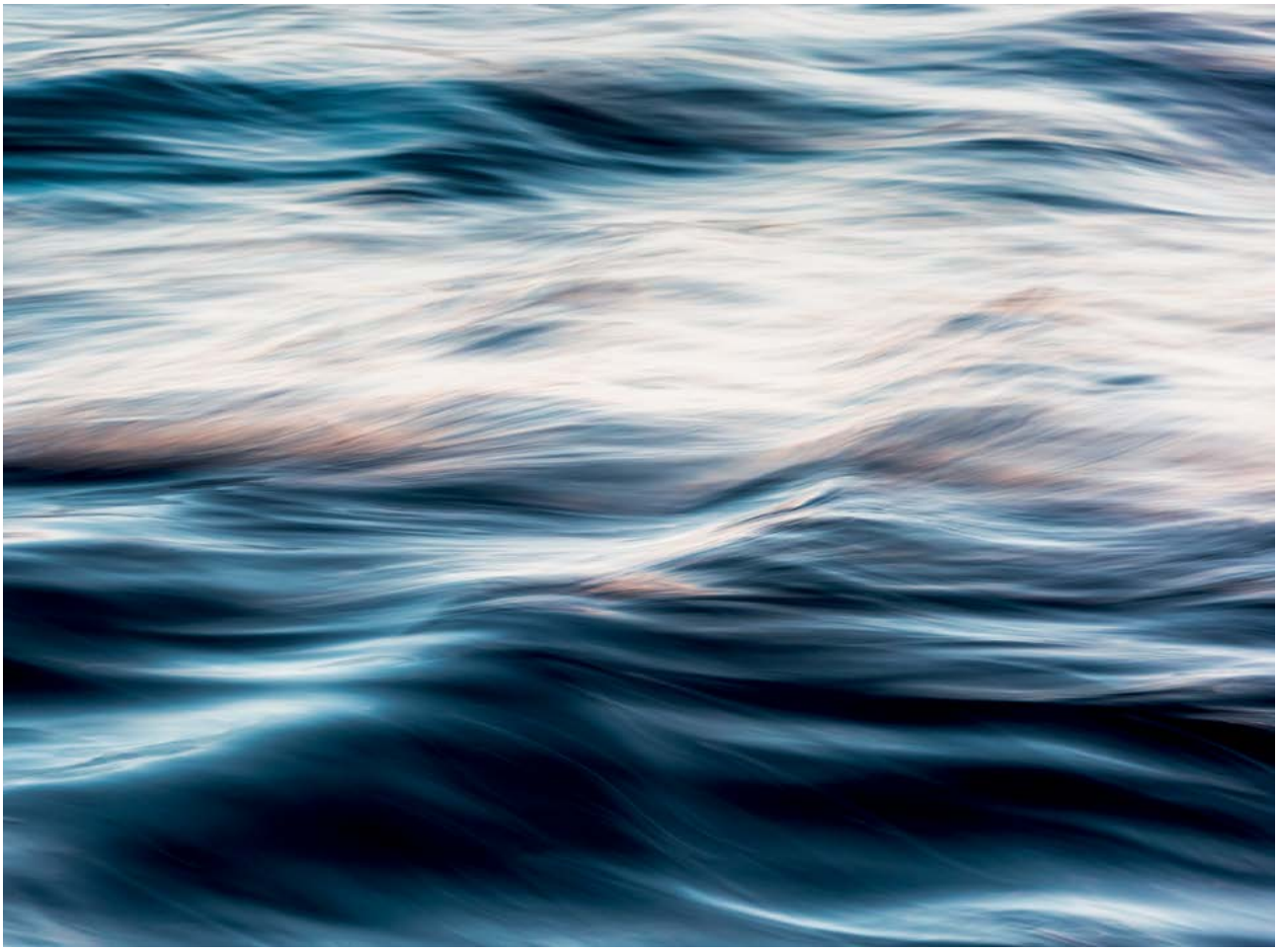
In 2019, the workshops were attended by various international tidal energy working teams, such as Dr. Jérôme Thiébot and his team from University of Caen, France, Dr. Sam Fredrickson and his team from University of Gothenburg, Sweden, Dr. Mathew Piggott and his team from Imperial College London, United Kingdom, Dr. Zhaoqing and his team from Pacific Northwest National Laboratory, Dr. Sam Fredriksson and the team from University of Gothenburg, Sweden, Dr. Prasad and his team from National Institute of Ocean Technology (NIOT), India, Dr. Venugopal Vengatesan and his team from University of Edinburg, United Kingdom, Dr. Balaji Ramakrishnan and his team from Indian Institute of Technology Bombay, India, Dr. Hong Zhang and his team from Griffith University, Australia, Dr. Philip Marsh and his team from University of Tasmania, Australia, and Dr. Narasimalu Srikanth and his team from Energy Research Institute @ NTU, Singapore.

Earlier, the International working group identified temperate waters of Alderney race straits, near Cherbourg, France, as common case study site. The chosen site case study was simulated by different international tidal energy working group members based on their chosen codes and with their modelling expertise for numerical comparison study. Each team presented their results to other international team members and had a detailed discussion on further improving the accuracy models through inclusion of various parameters. Based on the discussion, the other parameters that need to be included in each model were identified and they are as follows:

- Wind-wave generation:
  - Dominant wave types in terms of wave period/ frequency and amplitude
  - Classification and effects of damping parameters
- Wave-current interaction and wave breaking to address:
  - Resultant water surface elevation
  - Resultant direction of current
  - Basis for coupling between current and waves
  - Influence on tidal energy
- Modelling of the seabed and coastline depicting the quality of the sand in terms of its constituents for addressing the friction/drag force generated over the water flow.
- Effects of salinity and temperature in resultant tidal velocity and direction both qualitatively and quantitatively.

The International Tidal Energy Working Group has also prepared and submitted a joint comparison report and submitted it to OES for their feedback. A joint journal paper has also been prepared and submitted to a top tier journal based on the simulation models of the Alderney race case study.

As a further work, the international working group identified a Singapore site of tropical waters with available validation data as second case study. The International members were asked to include the various additional parameters such as wind wave generation (as mentioned earlier) in the new case study and were asked to simulate based on their chosen codes and with their modelling expertise for numerical comparison study. This would help in further code-to-code comparison of various models along with experimental validation data. It would also help in comparing the prediction accuracy of both tropical and temperate waters using various ocean models.



Ocean Thermal Energy Conversion

COORDINATOR

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

PARTICIPATING COUNTRIES

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

Objectives

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

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

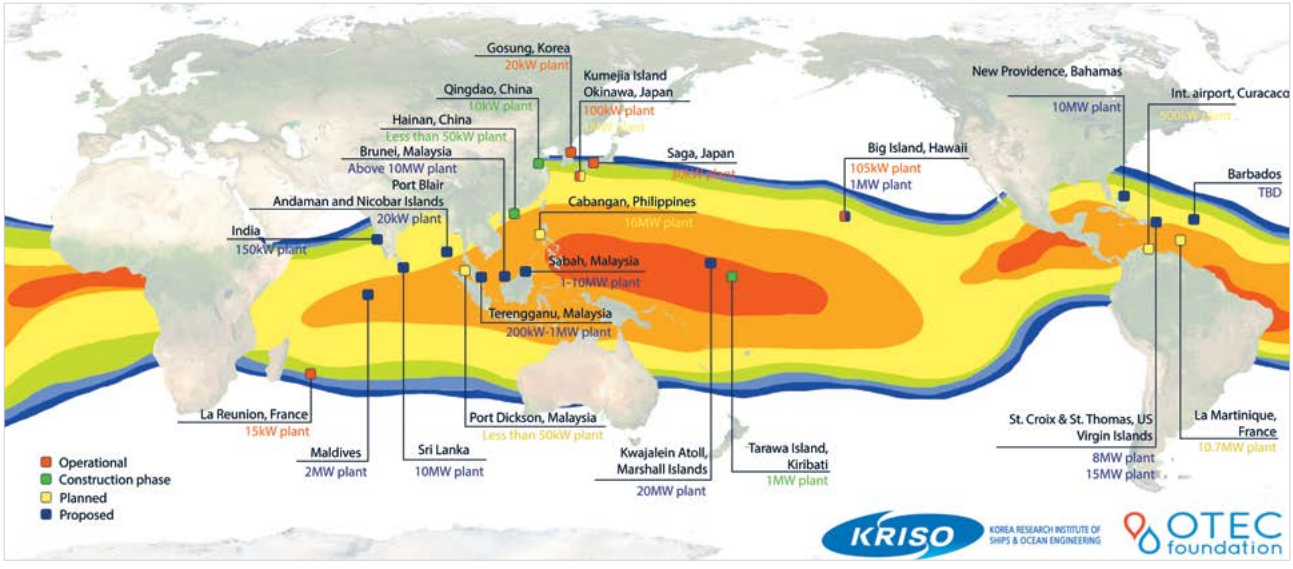
A state-of-the-art report of OTEC activities and projects around the globe has been prepared as a first step to further define a full work programme under this Task. The identification of plans and new developments on OTEC in the various regions of the world would be important for the development of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

Achievements

The Indian Delegate has been organising a series of webinars with the participants of the OTEC working group. Participants have been discussing the importance of promoting and disseminating knowledge on OTEC to the general public. Next chapter presents a summary of the OTEC activities in Republic of Korea.

In 2019, the 7th International OTEC Symposium was held in Busan, Republic of Korea (27 – 28 September) hosted by KRISO and the Korean Society of Power System Engineering (KSPSE). A meeting of the OES OTEC group was organized as a special session of the Symposium. Further during this event the OES Indian Delegate Dr Purnima has been awarded with the 2019 Uehara Prize for the contribution to the ocean thermal energy conversion.

A few recent progresses include the development of a 1 MW OTEC plant by KRISO in Republic of Korea; further Saga University has been working with Malaysia on building a new OTEC plant. A white paper on OTEC for policy makers is under preparation.



OTEC power plants

SPETIAL CHAPTER

Field Demonstration of Ocean Thermal Energy Conversion plant in Korean waters, Dr. Hyeon-Ju Kim (KRISO, Korea)

Ocean Thermal Energy Conversion (OTEC) is a technology that harnesses ocean energy. It generates power when warm surface seawater evaporates into a working fluid with low boiling temperature (e.g. R32), and the vapour rotates a turbine. Then, cold deep seawater condenses the fluid and it is recycled in the closed loop. This technology was first pioneered by a French scholar Prof. D'Arsonval in 1881, and then, Dr. Claude succeeded in operating a 22 kW-scale generator at sea around the year 1930. Subsequently, 50 kW ~ 210 kW pilot plant experiments were conducted by the U.S. and Japan from the 1970s to 2000s.

However, OTEC has not been put into practical use because a field demonstration and feasibility study on the MW-scale plant (which is deemed as semi-commercialization scale) has not been conducted yet. The Korean Government (Ministry of Oceans and Fisheries) supported a research consortium led by the Korea Research Institute of Ships and Ocean Engineering (KRISO) so that it can perform basic research and 20 kW pilot experiments. The consortium also finalized the design for the 1 MW offshore plant in 2015. Based on the design, the KRISO OTEC team manufactured the components for the 1 MW offshore plant, which is to be demonstrated in equatorial oceans. Turbine generator (2016), condenser 2017), evaporator (2018), refrigerant and seawater pumps (2019) were the major components for such an operation. During the summer of 2019 when typhoons were frequent, the OTEC plant was assembled onto barge Hundai Boryeong at Busan port. It was ready to carry out its performance test in the sea near Pohang-si from early September. Having waited for the waves to calm after successive typhoons (Pasai, Peipah, and Tapah), the barge left Busan port on 27th September and arrived at the point, which is 131 m water from Pohang-si on 28th September. Once four anchors and a riser were installed as designed, sensors were checked, and pumps were commissioned on 29th September. At noon of 29th September, a performance evaluation test finally identified the output of 338 kW by the difference between 24.8°C and 6.1°C. At present, the dissembled 1 MW OTEC plant is in storage waiting for its installation in Tarawa, Kiribati. Its parts will be transported and reassembled on land with an intake pipe in 2020. The long-term operation test for 2021 is planned to produce 1,000 kW at a temperature difference of 24°C (29°C-5°C). In addition, its system will be integrated into the current grid to reduce reliance on diesel generators. The commercialization of core technology, preceded by a successful demonstration of the 1 MW plant, will contribute to the low and mid-tropic regions in the oncoming climate crisis and achieve sustainable development.

1 MW OTEC Plant Installed in Experimental Waters (Pohang,'19)

Group photo after field experiment (Pohang, 2019)

Preparation for return after field test

Worldwide Web Gis Database for Ocean Energy

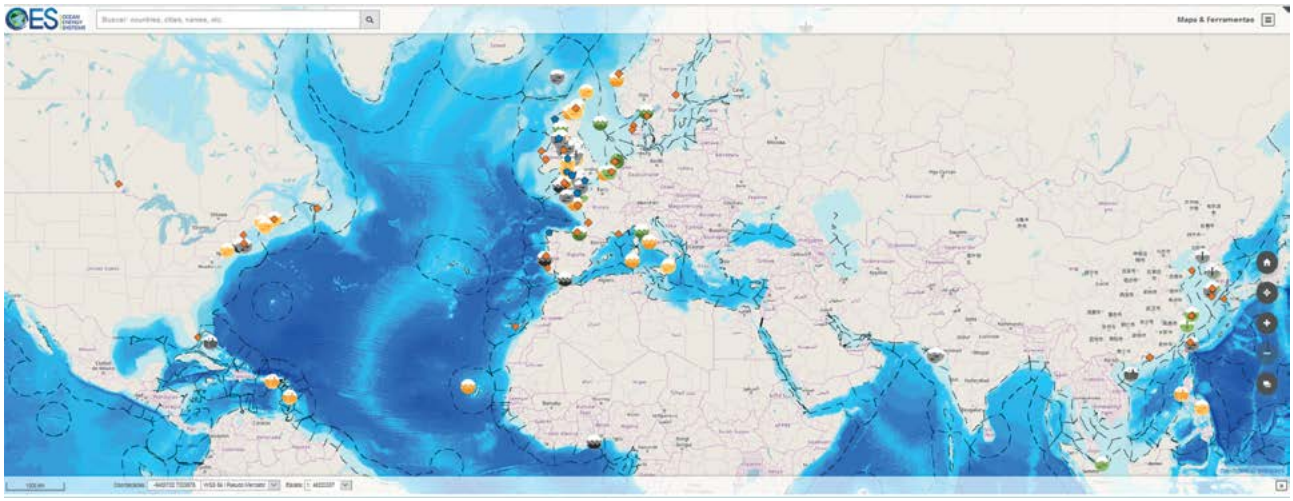
COORDINATOR
Jochen Bard, Fraunhofer Institute IEE, Germany

PARTICIPATING COUNTRIES
All Member Countries

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.



Web GIS Database: https://www.ocean-energy-systems.org/ocean-energy/gis-map-tool/

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.

In July 2019, a workshop on "Ocean Energy in Insular Conditions" was organised by the Oceanic Platform of the Canary Islands (PLOCAN), in Hawaii, with the support of OES. This workshop was the final one of a round of three events organized since 2017 in three different regions of the world, South-East Asia (Singapore), Europe (France) and the Pacific (Hawaii).

The main objective was to look at the opportunities and barriers to local adoption of ocean renewable energy on islands and isolated coastal communities of the Pacific from the perspective of various stakeholders, aiming to explore possible solutions to address the challenges identified. It tackled new business opportunities that could support ocean renewable energy's market take-off together with the crucial roles that each stakeholder has to play in contributing to the uptake of ocean renewable energy in insular regions and remote coastal areas. It was further an opportunity to present synergetic initiatives such as the MARINERG-I project to international stakeholders, which aims to accelerate the industry through the creation of a network of ORE facilities in Europe and possibly at worldwide level in the future.

Several issues have been identified as potential barriers for the development of ocean energy on islands and remote coastal areas, and the workshop enabled a set of recommendations for each topic discussed to be put forward.

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.

This topic was first discussed in 2012, in Dublin, in a workshop 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.

In October 2019, a workshop on open sea test sites was organised at the European Marine Energy Centre (EMEC) by the International WATERS group. This workshop aimed to share updates on progress and challenges from test sites 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. This was the second workshop on this topic supported by OES. The previous one, in 2018, was held in Taiwan 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.

03

INTERNATIONAL SITUATION ON OCEAN ENERGY

Australia

Overview

Engagement in the Australian ocean-energy sector has continued to grow in 2019. Some of the highlights this year included:

- An announcement in April of funding for a 10 year, $AUD 330M Blue Economy Cooperative Research Centre, to support sustainable growth of Australia's blue economy. One of the five streams of study within the Centre is "Offshore Renewable Energy Systems".
- Wave and tidal technology project development interest continued in 2019.
  - The MAKO tidal device completed a 6-month test, using existing wharf infrastructure in the Port of Gladstone, on Australian's east coast. Subsequent test deployment in is planned in 2020. MAKO also established a demonstration project in Singapore.
  - Wave Swell Energy began construction of their 250kW wave energy device in 2019 with planned deployment in King Island, Tasmania, in 2020.
  - Carnegie Clean Energy successfully overcame a significant business restructure in 2019 and are constructing their CETO 6 device for installation at Garden Island around the start of Q3 2020.
  - Four international companies began investigating opportunities to establish ocean energy projects in Australia.
- Australian Tidal Energy (AusTEN) project continued to assess the feasibility for tidal energy development in Australia. The AusTEN project research led to identification and selection of two tidal energy sites recommended for commercial development. Partner CSIRO is assessing the national tidal energy resource, for open-data distribution in 2020, identifying the economic opportunities for tidal energy as part of Australia's future energy mix.
- The Australian Ocean Energy Group (AOEG), a virtual ocean energy cluster, was formally established in early 2018 with seed support from the Australian Government' Industry Growth Centres Initiative, via National Energy Resources Australia (NERA) and start-up support from Climate KIC Australia. AOEG fully launched in 2019 with the year culminating with their signature event, an Ocean Energy Market Development Summit (mentioned above).
- An Ocean Energy Market Development Summit was implemented by the Australian Ocean Energy Group (AOEG) to establish a simultaneous customer-pull and industry-push, to encourage ocean energy development projects across Australia.
- OES membership continues to provide a foundation for cross-sectoral interaction within Australia and with the international community.
- Four Ocean Energy Sectoral electronic newsletters were published in 2019.

Supporting Policies for Ocean Energy

National Strategy

Current Renewable Energy policy in Australia consists of the Renewable Energy Target, to deliver 33000GWh of renewable electricity by 2020. In 2015, this target was reduced from 41000GWh. In September 2019, The Australian Clean Energy Regulator announced the Renewable Energy Target of 33000GWh had been met, over 12 months ahead of schedule.

Whilst not present at the Commonwealth level, Australian state-based renewable energy targets are in place. Australia Capital Territory (Canberra) has a 100% renewable energy target for 2020, with NSW, Victoria, Queensland, Northern Territory, SA, Tasmania having 2030 renewable energy targets of 46, 50, 50, 50, 100 and 100 per cent respectively. Western Australia is the only state of Australia that has not yet to commit to a renewable energy target.

There is no national Australian Ocean Energy Policy, Energy strategy, or related ocean energy study/roadmap/law related with ocean energy. However, Victoria, one of the 8 States/ Territories of Australia, is preparing a new marine and coastal policy.

The policy is a requirement under the Marine and Coastal Act 2018. A public consultation draft was released July 2019, and consultation closed in August 2019. The final policy is due for release in early 2020 – see https://www.marineandcoasts.vic.gov.au.

The policy has been developed with recognition of offshore renewable energy as an emerging offshore industry sector, and includes items of relevance to the ocean energy sector, as follows:

- Inclusion of a state-wide marine spatial planning framework;
- Policies of relevance to ocean energy;
- Clear guidance regarding marine and coastal structures, and
- Community Stewardship and Collaborative Management practices.

Also, a Victorian state Marine and Coastal Strategy will be developed in 2020 with an outline of the priority actions to achieve the Policy's objectives.

Public Funding Programmes

The Australian Renewable Energy Agency (ARENA) is the major source of government funds for ocean energy projects in Australia, with 14 ocean energy projects to date, 2 still current, including:

- Wave Swell project at King Island (TPC $12.3M AUD, ARENA contributing $4.03M), and
- AUSTEn Tidal Energy in Australia – mapping tidal energy (TPC $5.85M, ARENA contributing $2.49M) University of Tasmania partnering with CSIRO and Uni of Qld.

Australian OES membership is also funded by ARENA, is helping to strengthen domestic ocean energy community connections and networks. Four Australians attended the OES workshop on 'Ocean Energy and Islands Environment Workshop' in May. There is an Australian-initiated proposal for a task group on Off-shore, Off-grid Multi-use Platforms.

Research & Development

New Blue Economy Cooperative Research Centre was announced in April 2019. https://blueeconomycrc.com.au/. The Blue Economy CRC presents a 10-year commitment, via a $329M partnership across Industry, Government and the Research Sector, to support the sustainable development of Australia's blue economy. A management Board has been formed, and Dr. John Whittington appointed as the inaugural CEO in December. One of the Five streams of applied investigation in the Australian Blue Economy CRC will be: Offshore Renewable Energy Systems, with a total investment of $66M.

Program 3: Offshore Renewable Energy Systems

The objectives of the Offshore Renewable Energy Systems Research Program are to identify, develop and demonstrate offshore renewable energy systems capturing generation, storage and control aspects optimised for co-located offshore, off-grid operations.

Researching:

- **A.** Energy Demand (market assessment & modelling);
- **B.** Energy Availability (resource characterisation, & modelling);
- **C.** Conversion technologies (design & test), and
- **D.** Control Systems (develop integrated hydrogen microgrid systems).

AUSTEn Tidal Energy feasibility study http://austen.org.au/ is due for completion in June 2020, and is in its third, final year of the project. The project is led by The University of Tasmania (UTAS), and with collaborators University of Queensland are assessing the economic feasibility and ability of tidal energy to contribute to the country's energy needs.

Multi-day field campaigns in May, October and December took place to gather data to help understand the suitability of the AUSTEn project's two high potential tidal energy sites: The Banks Strait, Tasmania, and the Clarence Strait, Darwin. Characterisation of the sea included tidal speeds, bathymetry, water temperature, seabed composition and trends in fish behaviour. These field observations are being used to support development of numerical models of the two sites.

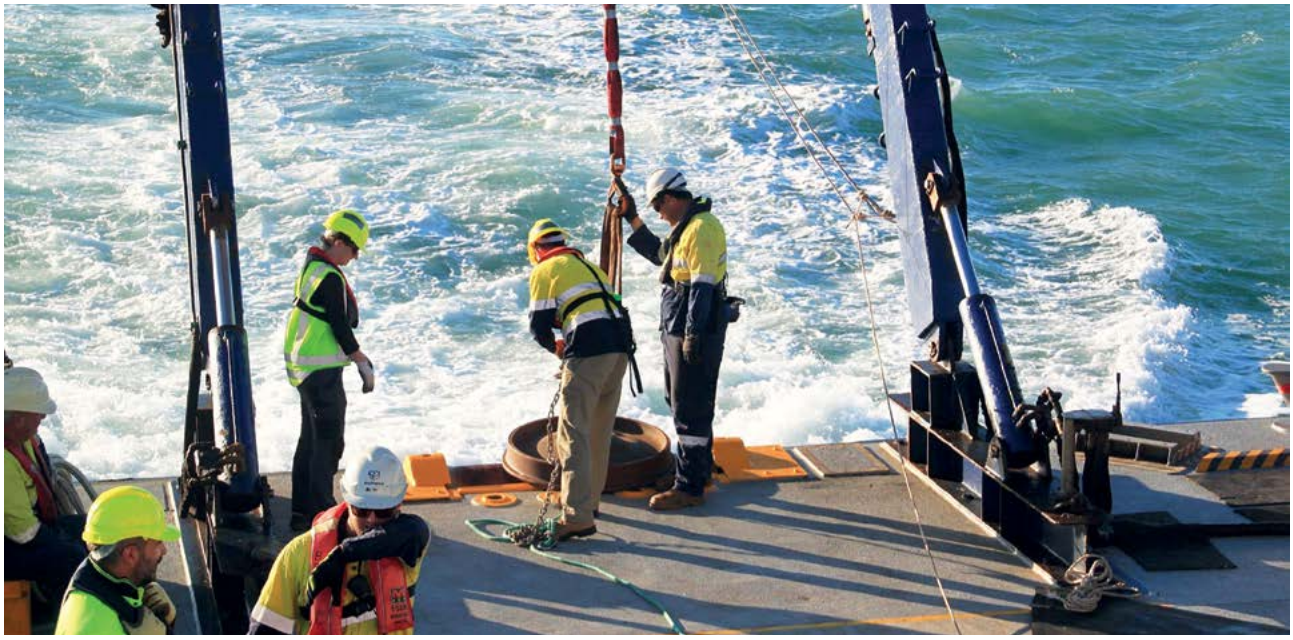
A multi-criteria assessment early in the project identified both Banks and Clarence Straits as promising locations for tidal projects, including predicted powerful tides, proximity to electricity grids, and nearby energy demand. The AusTEN study has provided further support to predictions that the two sites show promise for tidal energy development.

Project partner CSIRO continues with a national scale assessment of the resource, and feasibility of tidal energy as a contributor to Australia's future energy mix. An open-data release in 2020 is anticipated, via Australia's Renewable Energy Mapping Infrastructure and will sit alongside the Australian Wave Energy Atlas.

University of Western Australia - Wave Energy Research Centre (WERC) - undertakes multidisciplinary research that is critical to finding cost-effective ways of generating wave energy on an industrial scale. The WERC has three main research programmes:

- Coastal processes: looking at the wave and current conditions at the development site to successfully deploy wave energy converters.
- Hydrodynamics: working with the Albany Wave Energy Project to characterise the device-wave interactions and design the latest technology in wave energy converters.
- Foundation engineering: developing solutions to meet the specific requirements of the marine renewable energy industry.

Environmental assessment study at Gladstone EET installation - Programme participant, James Cook University, released their report on using artificial intelligence (AI) to review underwater video streams to identify environmental impact of the MAKO. No adverse impacts were detected, and the system is proving highly cost-effective and accurate in gathering data for regulators.



Field Operations in Clarence Strait near Darwin Aus (Source: http://austen.org.au/index.php/news/)

Technology Demonstration

Projects in the Water

MAKO Tidal Turbines continues to develop its MAKO tidal energy system, a scalable and modular hydrokinetic turbine suitable for attachment to existing structures and in shallow water and has been in operation for more than 6 months at Gladstone Port, on Australia's east coast. MAKO collaborated with James Cook University for data collection and analysis. are also demonstrating their turbine at Saratoga Island, Singapore, pioneering attachment to an existing bridge structure.

MAKO tidal energy system at the Port of Gladstone

Planned Deployments

Wave Swell Energy continues successful development of their 200 kW pilot King Island Demonstration Project in Tasmania. Construction is underway, with deployment anticipated in the first half of 2020.

More information: https://arena.gov.au/blog/king-island-wave-power/.

Relevant National Events

- The Australian delegate to OES, and the AOEG hosted webinars after each of the two OES Ex-co meetings in 2019 to share the information and outcomes of the Australian participation in the OES.
- AOEG facilitated completion and submission of an application to Standards Australia to form an Australian "Mirror Committee" to the international Marine Energy Standards, Technical Committee 114 (TC114). The inaugural Australian working group was established, and Australia's application was submitted in November 2019. A decision by Standards Australia is expected in early 2020.
- The biennial Australian 'Forum for Operational Oceanography' – was held in October 2019, and included presentations on Marine Renewable Energy, within a theme of 'Opportunities for operational oceanography to drive the development of Australian marine industries' https://www.foo.org.au/forum/foo2019/.
- An Ocean Energy Market Development Summit was held in December 2019 in Sydney, to establish a simultaneous customer-pull and industry-push in order to increase the number of ocean energy development projects across Australia. The Summit was implemented by the Australian Ocean Energy Group (AOEG). An important takeaway from the Summit was: there will not be a one size fits all in ocean energy. There is a recognition of the very diverse wave and tidal technologies in development and how they are suited for varied ocean environments – such as deep and shallow waters, fast and slow flowing waters and other factors. Therefore, the future market success will depend on fulfilling the market need with the right ocean energy technologies and systems. Next steps are to translate this valuable information and networks into practical roadmaps to connect key markets with ocean energy suppliers and systems.
- A workshop on state of the science on environmental effects of marine renewable energy was held in December 2019. The workshop examined pathways for determining data needs, and monitoring requirements, and included discussion on possible mitigation measures for two stressors—electromagnetic fields and underwater noise—seeking solutions for small installations of tidal and wave energy converters. This workshop was hosted by OES-Environmental (formerly Annex IV) and ORJIP Ocean Energy and held at the University of Technology Sydney.

This year, the Australian community has spent time in 2019 preparing for events planned for 2020, when Australia will host three international and one national Australian Ocean Energy events, including:

- **The 5th Asian Wave and Tidal Energy Conference** will be held in Hobart, Australia on 8-12 November 2020. Abstracts are due by 1 March 2020.
- **The 3rd Australian Ocean Renewable Energy Symposium** (AORES) will be featured within AWTEC 2020, highlighting the growth of Australia's renewable energy capabilities and developments.
- **The 39th OES ExCo** meeting will be held in Tasmania in November 2020.
- **The 31st International Conference on Coastal Engineering (ICCE) 2020** will be held in Sydney, September 2020, with a marine renewable session planned (http://icce2020.com/).

Belgium

Overview

Ghent University is coordinating the European COST Action CA17105 WECANet, an open pan-European Network for Marine Renewable Energy with a focus on wave energy. This project is funded by the European COST Association and involves 31 countries. WECANet targets scientific excellence and inclusiveness by fostering training, networking and collaboration in Europe for wave energy.

The Coastal Engineering Research Group (CERG-UGent) is an international player in the field of Blue Energy with its pioneering research tools. CERG-UGent focuses on the research topics of wave and tidal energy, and offshore floating wind turbines and other floating structures, and is pioneer in investigating parks of energy devices. The group's integrated approach is based on numerical and experimental modelling, and field measurements. For this purpose CERG develops a range of numerical models and instrumentation, while the group's access to infrastructure includes the 'wave & current flume' at the Technologiepark Campus Ghent, the 'Blue Accelerator test site' in the Ostend harbour, and the 'Coastal & Ocean wave & current Basin' in Ostend. Ghent University 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).

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

An 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.

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. The Blue Energy Cluster of POM West Flanders was established by the province of West Flanders to give businesses in this industry every possibility to grow via innovation. Promotion, research, training and infrastructure. The cluster partnerships aim to create an optimal breeding ground for a future-oriented economy. This is possible thanks to a close collaboration between education, science, industry and local government. The latest development was the installation of a new offshore maritime innovation and development platform by POM, the Blue Accelerator, offering both the industry and knowledge institutions the opportunity to develop and test new products and technologies in real life sea conditions.

Moreover, POM has introduced TUA West (Technical University Alliance West Flanders), 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 focus is on improving cooperation between the province's higher education establishments and making knowledge more readily available to the industry and especially the many SMEs in the region. The TUA West Expert Group on Blue Energy pools the expertise of Ghent University, Howest, KU Leuven, OWI-Lab, Sirris, VIVES and VLIZ in the field of energy production from or at sea. Their activities related to research and valorization are centralized around the test infrastructure located at West Flanders. The Expert Group encourages the use of this infrastructure by setting up research projects in which the knowledge institutions participate in favour of and in collaboration with the Blue Energy sector.

The Blue Growth Summer School organised by Ghent University is recognized by the European Commission as best practice example of innovative training. Already four years on row, the BGSS has fostered blue knowledge and received a variety of participants. The programme combines fundamental insights with hands on session and site visits. Besides professors also business developers, entrepreneurs and industrial leaders share their expertise with Master and PhD students passionate about the seas and oceans.

More information: http://www.bluegrowth.ugent.be/summerschool/

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 past years. Currently, Belgium's renewable energy share is at around 9%. 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 2.262 MW of offshore wind power installed by end 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.

In the coastal province of West Flanders, Western part of Belgium, marine renewable energy is seen as a new emerging industry, highly relevant for Flanders. 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 Flemish Agency for Innovation and Entrepreneurship (VLAIO) has been supporting the 'Innovative Business Network Offshore Energy' and the 'Blue Cluster' aimed at large companies & SMEs active in the blue economy sector, including marine energies.

The West Flanders Development Agency (POM West Flanders), is supporting developments in the blue energy field, promoting the development of ocean energy technology by the academic sector and private companies. The Blue Energy Cluster of POM West Flanders was established by the province of West Flanders to give businesses in this industry every possibility to grow via innovation. Promotion, research, training and infrastructure. The cluster partnerships aim to create an optimal breeding ground for a future-oriented economy. This is possible thanks to a close collaboration between education, science, industry and local government. One example is the periodic, structural meeting of the "core group" blue energy, organised by POM West Flanders, which brings together the main players in the blue energy field.

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 domanial concessions for renewable 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.

IBN-Offshore Energy

The IBN-Offshore Energy is a network of Flemish companies innovating in the field of offshore energy (offshore wind, floating wind, wave & tidal). The activities are oriented towards facilitating innovation in this area, the mission of the support team is to support the process from back of the envelope idea towards a project plan for an innovative product or service ready to be executed.

More details: https://www.clustercollaboration.eu/cluster-organisations/ibn-offshore-energy-owi-lab

Members list:

The Blue Cluster

The Blue Cluster (www.blauwecluster.be) has been established by Jan De Nul, Colruyt, DEME, Econopolis, INVE, Sioen Industries, Tractebel Engineering, Vanbreda Risk & Benefits, Vyncke and ZERI. In the first working year of the Blue Cluster a total of 7 projects have been approved by Flemish Agency for Innovation and Entrepreneurship (VLAIO), representing a total budget of € 10.423.738 (subsidy € 6.995.923). The Blue Cluster was recognized by the Flemish government as a spearhead cluster in March 2018. At the end of 2017, Colruyt, DEME, Econopolis, INVE, Jan De Nul, Sioen Industries, Tractebel Engineering, Vanbreda Risk & Benefits, Vyncke and ZERI set up Blue Cluster as a partnership that focuses on the development and promotion of economic activities at sea.

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 in Scotland 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 wave energy converters on their suitability to be integrated in seaport infrastructures and bring the selected concepts to the next TRL. More information at: http://oceaneranet.eu/portfolio/seports/
- 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 Laborelec (www.laborec.com) is involved in the WindFloat Atlantic floating offshore wind power development off the north coast of Portugal. This pilot installation will use 3 or 4 generators to provide a total generating capacity of 25 MW and will be built on semi-submersible foundations designed by Principle Power.
- 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, 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 of West Flanders established cluster platforms in the framework of the Provincial Development Agency West-Flanders (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. 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.

See also the international brochure: http://www.investinwestflanders.org/sites/default/files/Blue_Energy.pdf

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

Public Funding Programmes

Every year, POM West Flanders launches a call for project called the "Quick Wins", in which a number of short-term innovation cooperation projects are funded (50%) with the ambition to finalise with a pilot installation, test setup or prototype.

The Belgian 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 in accordance with article 3, §1, of the Royal Decree of 9 May 2017 laying down the conditions for use of the Energy Transition Fund. The current call aims to support innovative and research projects within five energy sectors 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 25 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.

The Flemish Agency for Innovation and Entrepreneurship (VLAIO) has been supporting the 'Innovative Business Network Offshore Energy' (IBN-Offshore Energy) since 2017, and since 2018 VLAIO set up the 'Blue Cluster' aimed at large companies & SMEs active in the blue economy sector, including marine energies. In the first working year of the Blue Cluster a total of 7 projects have been approved by Flemish Agency for Innovation and Entrepreneurship (VLAIO), representing a total budget of €10.423.738 (subsidy € 6.995.923).

Research & Development

Coastal & Ocean Basin

The construction of the new Coastal and Ocean Basin (COB) (www.cob.ugent.be) in Ostend has been completed. 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 Flemish Ministry of Mobility and Public Works. The exploitation will be managed by Ghent University, KU Leuven and Flanders Hydraulics Research. The basin is equipped with a unique combination of a narrow paddle wavemaker in L-shape and a bidirectional current system, to achieve high quality short-crested waves at almost any relative angle with the current. The COB is 30 m long by 30 m wide and has a variable water depth up to 1.4 m, allowing for test conditions from coastal to near offshore applications. A pit located in the middle of the basin allows experiments with mooring lines at a depth in excess of 4 m.

The Coastal & Ocean Basin, together with the new towing tank, forms the Flanders Maritime Laboratory.

WECANet

The European COST Action CA17105 "**WECANet** (www.wecanet.eu) is a network of 31 countries dedicated to Marine Renewable Energy, with a focus on Wave Energy. It is coordinated by the Coastal Engineering Research Group of Ghent University (UGent-CERG, http://awww.ugent.be). 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 targets scientific excellence and inclusiveness by fostering training, networking and collaboration in Europe for wave energy. In 2019, WECANet has funded research collaborations through Short Term Scientific Missions and meetings, international Wave Energy Training Courses and dissemination activities and scientific publications on wave energy.

1st WECANet Assemblies in Thessaloniki (February 2019)

MARINERG-i

Ghent University is strategic partner in the H2020 MARINERG-i project coordinated by the MaREI Centre at University College of Cork in Ireland, which brings together all the European countries with significant testing capabilities in offshore renewable energy. 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).

MET-Certified

POM West Flanders and Ghent University are partners in MET-Certified, an Interreg 2 Seas project aimed at the development of international standards and certification for marine energy technologies.

COASTAL

COASTAL, a Horizon 2020 project, 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.

More information: https://h2020-coastal.eu

OPIN

Sirris from Belgium is partner in OPIN (Ocean Power Innovation Network), an Interreg North West Europe project from the European Research and Development Fund (ERDF). OPIN is a cross-sectoral collaborative network that aims to accelerate the growth of the ocean energy sector and its supply chains across the partner regions of Belgium, Ireland, the UK, France, the Netherlands and Germany.

NON-STOP

NON-STOP is an abbreviation for "New smart digital Operations Needed for a Sustainable Transition of Ports", funded by the North Sea Region Programme (2014–2020). Belgian partners are the Port of Oostende, CRESCENT NV and Bluebridge. The project focuses on small and mediums sized Ports (SMP) within the North Sea Region, which have

been working in complex and rapidly changing world where the society and businesses have experienced a digital transformation in numerous areas. The ultimate goal is to reduce the time of pre-defined logistical/ maintenance port operations and lower port energy and pollution.

More information: https://northsearegion.eu/non-stop/about/

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, 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/

ELBE project

Five European clusters, including Flanders' Maritime Cluster (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. In addition, an analysis is carried out of the challenges for marine energy technologies, new value chains and opportunities for companies, also for companies that are not necessarily involved in this sector. This project is supported by the EU COSME-programme.

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

The new "Blue Accelerator" test platform

Within the framework of the BLUE ACCELERATOR project, testing facilities are realized on/near/offshore with the aim of creating a Living Lab, based in Ostend, where testing is possible under real sea conditions. In the BLUE ACCELERATOR project, a unique maritime test platform (500 m outside the port) has been built to perform tests in the context of the development of Blue Energy projects (offshore wind energy, wave and tidal energy) and the broader Blue Economy. The Blue Accelerator project is funded by the European Regional Development Fund (ERDF), with co-financing by the Flemish government (Hermes Fund). The project is coordinated by the Provincial Development Agency (POM) West Flanders, with the project partners Ghent University, VLIZ, Vives, VITO and TUA West. The maritime test platform has been developed by Nemos GmbH and is adopted by POM.

More information: http://www.pomwvl.be/blue-accelerator.

MPVAQUA

The BLUE CLUSTER MARINE FLOATING PV Project consortium aims to develop an innovative technology or product concept as well as know-hows for an offshore marine floating PV (MFP) technology to generate electricity for aquaculture at the nearshore of the Belgian North Sea. The Phase I – Feasibility of the BLUE CLUSTER MARINE FLOATING PV Project aims to develop several innovative concepts for offshore marine floating PV for use with aquafarm, and to assess the feasibility of these developed concepts via several outdoor/field test benches. This project is funded by the BLUE CLUSTER (VLAIO).

Sweet-H2O

This feasibility study wants, by joining the expertise of different Flemish SMEs, public companies and centres of excellence for water research, to evaluate if central and/or decentral sustainable seawater and brackish water desalination offers possibilities as an additional water supply for Flanders. As state-of-the-art seawater desalination has a high energy demand, this study will evaluate innovative energy efficient treatment systems that use smart renewable energy resulting in combined water production and storage of renewable energy as Hydrogen. This project is funded by the BLUE CLUSTER (VLAIO).

MFiLand

Many societal challenges (climate change, flooding due to sea level rise, water scarcity, etc.) can be tackled in a marine and maritime context. Within this context, the MFiLand project aims at applying an innovative "integrated, multi-use solution for multiple problems" approach instead of the common "single solution for single problem" approach. The proposed solution encompasses the ecosystem-based construction and operation of a man-made, multifunctional island, off the Belgian coast, called "MFiLand". The construction of this MFiLand will be preceded by the construction of a demonstration island, called "Demo MFiLand". This project is funded by the BLUE CLUSTER (VLAIO).

Four PhD research projects at Ghent University dedicated to wave energy research

The Research Foundation Flanders (FWO, https://www.fwo.be/) is funding four PhD research projects, carried out at the Coastal Engineering Research Group of Ghent University. Four of these PhD topics focus on the numerical and experimental modelling of Wave Energy Converter arrays/farms for simulating near- and far-field hydrodynamic effects. Moreover, FWO approved funding for developing and constructing wave energy array scale models to be tested soon in the Coastal and Ocean Basin in Ostend.

BlueBridge

BlueBridge is an incubator/innovation centre focused on blue growth located in West Flanders covering marine and maritime topics. It is located in the high-tech knowledge hub Ostend Science Park (OSP) in the inner port of Ostend, covering marine and maritime topics.

Technology Demonstration

The NEMOS Wave Energy Converter is an innovative system for generating electricity from ocean waves and is currently deployed at the Blue Accelerator of POM West Flanders. The prototype features a 8 x 2 m floater and a 16 m long substructure (source: www.nemos.org).

The Flemish wave energy developer Laminaria is developing a 200 kW prototype tested at EMEC's grid-connected wave test site, through the European funded project LAMWEC (source: http://www.laminaria.be/lamwec.html)

POM West Flanders will be fully operational starting in spring 2020. From then on, companies and knowledge institutions active in blue energy, or broader blue growth, can test and demonstrate new products and technologies in real life living conditions, with quick access, easy permitting via POM, access to a large blue energy network and tailor-made support by the involved Flemish partners.

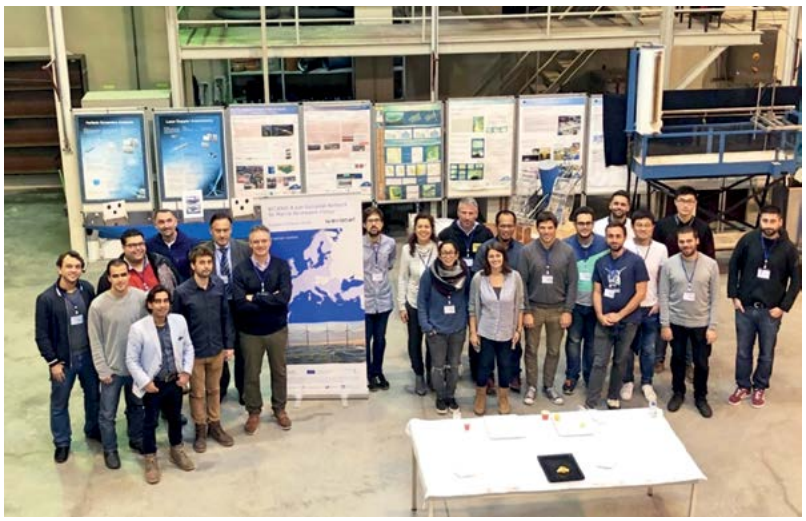
Relevant National Events

2019

- Blue Growth Summer School organised by Ghent University, September 2019; http://www.bluegrowth.ugent.be/summerschool/
- Belgian Offshore Days, 18-19 March.
- Taskforce AR/VR – Blue Cluster in cooperation with IBN Offshore Energy, 5 April 2019.
- Taskforce Offshore Energy – Blue Cluster in cooperation with IBN Offshore Energy and the Belgium Offshore cluster, 29 August 2019.
- Short course 'numerical coupling methodologies for modelling of wave energy converters (and arrays)', 27 November 2019 in Porto, Portugal; Organised by Ghent University and funded by WECANet.

2020

- 2nd Coastal & Ocean Basin (COB) Seminar, 6 February 2020, organised by Ghent University on recent innovations in experimental research in a wave tank facility.
- IBN Offshore Energy - Offshore Floating Marine Renewable Energy Technologies, 5 February 2020.
- Taskforce Ancillary services in the Offshore grid at the IEEE sustainable summit in Brussels – Blue Cluster in cooperation with Flux50, 24 March 2020.



Participants of the WECANet short course on 'Numerical coupling methodologies' organised on 27 November 2019 in Porto, Portugal.

Canada

2019 has been an important year for Canada's marine renewable energy sector – with many development approvals now in place and plans for commencing deployments over the next 1-2 years.

Overview

On the east coast of Canada, the success of policy and other supports is evident with the Bay of Fundy's world-class tidal resource attracting the interest of developers from around the world. DP Energy, Sustainable Marine Energy, Minas Tidal, Big Moon Power, Jupiter Hydro, and Nova Innovation have received permits from the Government of Nova Scotia for development in the province and are all working towards deployments in the next 1-2 years. The Government of Canada has also had a huge impact in supporting these projects and most recently awarded DP Energy $29.7M under its Emerging Renewable Power Program (ERPP) for the 9MW Uisce Tapa project being developed at FORCE.

Other regions of Canada are also making progress in tidal, wave, and river current energy – many with a focus on providing clean electricity to remote communities. Renewable energy for coastal and remote communities is being enabled and supported through the Pacific Regional Institute for Marine Energy Discovery (PRIMED), which is aimed at eliminating the uncertainty and risk for "first-of-a-kind" community based marine renewable energy projects. Developers such as Yourbrook Energy Systems and ORPC Canada are advancing steps to bring marine renewable energy to remote communities in British Columbia and Quebec.

The Canadian marine renewable energy sector has continued to conduct important R&D and innovation activities through FORCE, Sustainable Oceans Applied Research (SOAR), University of Victoria/PRIMED, and the Canadian Hydrokinetic Turbine Test Center (CHTTC). In 2019, Canada also continued to excel at understanding the marine resource and assessing environmental interactions through research supported by the Offshore Energy Research Association (OERA). The federal government through CanmetENERGY-Ottawa, Natural Resources Canada and National Research Council has also completed the marine renewable energy resource atlas for British Columbia in western Canada and is leading a River Hydrokinetic Energy Resource Assessment project.

Supporting Policies for Ocean Energy

National Strategy

Canada's Marine Renewable Energy Technology Roadmap continues to be the primary strategy and action plan for wave, in-stream tidal, and river current energy in Canada. Progress continues towards achieving actions and goals identified by the roadmap, with industry and researchers implementing various activities out of necessity to advance the sector.

As of 2019, many of the programs and policies under the Pan-Canadian Framework for Clean Growth and Climate Change have been rolled out and implemented. The Framework is an umbrella to many of the programs and policies that support renewable energy development in Canada, and therefore, it plays a key role in the marine renewable energy sector.

Over the course of 2019 the Government of Canada was focused on progressing and implementing a number of key priorities – several of which had relevancy to the marine renewable energy sector. on June 2019, the Senate passed Bill C-69, which included new legislation affecting the regulation of the energy sector and marine renewable energy – the Canadian Energy Regulator Act (CERA), the Impact Assessment Act (IAA), and the Canadian Navigable Waters Act. The Fisheries Act was also substantially amended. The new Canada Energy Regulator (CER) under CERA now has a mandate to cover emerging energy developments such as the regulation of offshore renewable energy.

The Impact Assessment Act (IAA) creates the new Impact Assessment Agency of Canada and repeals the Canadian Environmental Assessment Act. The process to establish the IAA also included changes to the Project List Regulations under the IAA which address in-stream tidal energy and offshore wind project thresholds, setting a threshold for in-stream tidal energy projects larger than 15 MW to undergo processes under the IAA.

The Geological Survey of Canada is currently conducting a review and assessment of seabed foundation conditions in the offshore regions of the Maritimes. The resulting report will summarize seabed composition, morphology, stability, and geotechnical properties, based on existing data. The report will be released publicly in 2020 and is expected to be useful for anyone considering future, marine renewable development projects.

The hub for tidal energy development continues to be on the Atlantic coast in the province of Nova Scotia. Nova Scotia's Marine Renewable Energy Strategy (2012) continues to be implemented, providing pathways and support for demonstration to commercial development of the sector including a demonstration permit program

that was launched in 2018. Under the program, marine Renewable-energy permits let project developers test or demonstrate new ways of generating marine renewable energy. Applicants may apply for unconnected permits to test non-grid connected devices or demonstration permits to deploy and connect devices to the electrical grid in the Province. Each demonstration project may be permitted no more than five 5 MW of new generating capacity, with a total of no more than 10 MW available under the program. To date, 7 MW have been allocated (5 MW allocated to Big Moon Power in 2018; 2 MW allocated to Jupiter Hydro in 2019; and 1.5 MW allocated to Nova Innovation in 2019).

The Government of Nova Scotia also amended its *Marine Renewable Energy Act* to allow for extensions of FITs/PPAs for tidal energy developers currently working at the FORCE site. This allows for current investments and activities to be built upon and provides an opportunity for developers to attract future support and investment.

Nova Scotia also initiated a call for proposals for the vacant berth at FORCE which has been occupied by Cape Sharp Tidal's OpenHydro turbine. A third party administrator is conducting the process on behalf of the government and will only consider proposals that include a private sector solution for the Cape Sharp turbine and will have the authority to issue a power purchase agreement and a licence, if there is a successful proposal. The project size will be limited to no more than 4 MW at a maximum rate of 53 cents/kWh. Companies will be required to have a minimum of $4.5M in security to cover all costs associated with the Cape Sharp turbine and additional security will be required before any new device is deployed.

The Government of British Columbia released its CleanBC plan, a pathway to achieve the Province's legislated climate targets of reducing greenhouse gas (GHG) emissions by 40% by the year 2030, based on 2007 levels. The plan describes and quantifies measures that will eliminate 18.9 megatons (Mt) of its 2030 target under three categories: Transportation, Buildings, and Industry. A key action of the plan is support for communities, including helping "remoted communities reduce dependence on diesel".

Market Incentives

Under Nova Scotia's *Marine Renewable Energy Act*, projects that receive a permit can also receive a power purchase agreement (PPA) of up to 15 years. Any utility in Nova Scotia is required to procure all electricity under the PPA.

Two projects at FORCE have approvals for Nova Scotia's 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: 1) DP Energy's Uisce Tapa Project and 2) Spicer Energy's Pempa'q project (a joint venture between Sustainable Marine Energy and Minas Tidal Ltd.).

Projects in other areas of Nova Scotia and the Bay of Fundy are also able to receive a FIT under Nova Scotia's demonstration permit program. To date, Big Moon Power, Jupiter Hydro, and Nova Innovation have all received approvals under the permit program.

Public Funding Programmes

The Pan-Canadian Framework on Clean Growth and Climate Change along with the federal government's 2017 Budget, included a number of programs that could support the marine renewable energy development.

Notably, the Clean Growth in Natural Resources Program (budget of $155M over 4 years) the Emerging Renewable Power Program (budget of $200M over 5 years) has supported marine renewable energy projects.

In 2019 a new program was introduced – Breakthrough Energy Solutions Canada. In partnership with Breakthrough Energy, Natural Resources Canada (NRCan) launched a $30M call for proposals aimed at leverage financing and expertise to support the advancement of Canadian clean energy technologies that can significantly reduce greenhouse gas (GHG) emissions. Breakthrough Energy Solutions Canada also partnered with the Business Development Bank of Canada (BDC), allowing cohort projects to benefit from BDC's experience as well as a further investment of up to $10M for successful cohort companies.

Research & Development

Fundy Ocean Research Center for Energy (FORCE)

Fundy Ocean Research Center for Energy (FORCE) has witnessed an increase in new technology activity since the demise of OpenHydro last year. Recent activity includes:

- The Province of Nova Scotia licensed SME to bring its technology to FORCE as a 1.26 MW tidal array.
- DP Energy announced the successful deployment of tidal current sensors on their site at FORCE, with support from Canadian companies Seaforth Geosurveys and Huntley's Sub Aqua Construction, in preparation for a nine-megawatt tidal system.
- Appointment of FORCE's Science Director to be Canada's leading expert in the "State of the Science Report 2020".

Monitoring activities at FORCE from May 2016 to present have been conducted with academic and research

partners, including Acadia University, Envirosphere Consultants, GeoSpectrum Technologies Inc., JASCO Applied Science, Luna Ocean Consulting, Nexus Coastal Resource Management, Ocean Sonics, Sea Mammal Research Unit Consulting, and the University of Maine. FORCE's cumulative totals represent more than 2,700 'C-POD' marine mammal monitoring days, more than 400 hours of hydroacoustic fish surveys, bi-weekly shoreline observations, over 50 observational seabird surveys, four drifting marine sound surveys and additional sound monitoring, and 11 days of lobster surveys using 32 traps.

Offshore Energy Research Association (OERA)

The Offshore Energy Research Association (OERA) has supported a diverse number of research studies and initiatives over its 13-year history facilitating in tidal energy development. OERA's marine renewable energy research highlights for 2018-2019 include:

- Advancements in how to optimize tidal, wind and solar electricity generation using energy storage (Dr. Swan, Dalhousie University).
- Development of a new subsea 'dynamic mount' platform structure, that significantly improves the field of view for monitoring marine life near turbines in high flow conditions (Open Seas Inc. and FORCE).
- Quantifying fish-turbine interactions using innovative high residency acoustic electronic fish tagging technology (Dr. Stokesbury, Acadia University and VEMCO).
- Laboratory testing of a wind turbine retrofit –the 'Power Cone' along with new composite blade materials, that together are showing promise for adaptability and use in improving tidal turbine performance (Biome Renewables, Glas Ocean, Dalhousie University, & Alison Mark consulting).
- Development of a wireless communication link for use in monitoring the presence and location of marine mammals in real-time around tidal turbines (Dr. Bousquet, Dalhousie University & Ultra Electronics).

OERA, in partnership with FORCE, also launched the Pathway Program - a multi-year initiative to define, test and validate an environmental monitoring solution for tidal energy development. The program goal is to create an integrated sensor technology system that brings regulatory acceptance and approval, facilitating in the development of marine renewable energy projects in Canada.

Sustainable Oceans Applied Research (SOAR)

Sustainable Oceans Applied Research (SOAR) is a not-for-profit organization working to help establish an area of Nova Scotia – Digby Neck and Islands – as a globally recognized focal point for marine renewable energy and smart-grid innovation – with further application throughout Canadian remote communities, and beyond. As an initial step, SOAR has been working to advance tidal energy projects in Grand Passage and Petit Passage in the Bay of Fundy as a crucial component of sustainable, clean, and secure coastal community power systems. To help enable this, SOAR has been working with local communities, industry, and academics to advance research, and understating of tidal energy, while establishing shared use marine infrastructure.

SOAR's largest active research project is in partnership with the Canadian Hydrokinetic Turbine Test Centre (CHTTC), which has collectively secured $1.4M through Natural Resources Canada's (NRCan) Clean Growth Program. The project runs through March 2021 and is titled "Addressing technical challenges to enable hydrokinetic clean power generation in river and coastal communities." SOAR is leading 3 work packages, including: 1) Best practices for site assessments at remote locations; 2) Monitoring marine animals at tidal energy sites; 3) Turbulence/wake assessments.

Left to right, Dr. Len Zedel (Memorial University), Greg Trowse (SOAR), Mark Downey (Memorial University), Muriel Dunn (Memorial University), and Gavin Feiel (SOAR) on the Kipawo (Huntley's Sub-Aqua Construction) prior to deploying co-located BioSonics DTX split-beam echosounder, RDI Workhorse ADCP, and Sub Aqua Imaging optical camera. Image credit: Huntley's Sub-Aqua Construction.

University of Victoria (IESVic)

The University of Victoria (UVic) has been leading work in wave energy and clean energy for remote community development, working with local suppliers, industry, researchers, and Indigenous communities. UVic continues to lead this work through its established Pacific Regional Institute for Marine Energy Discovery (PRIMED), which is aimed at eliminating the uncertainty and risk for "first-of-a-kind" community based marine renewable energy projects.

Key projects and activities over 2019 included:

- Research methods for extreme wave assessment in coastal waters;
- Wave measurement and instrument development;
- Microgrid assessment for Hot Springs Cove Hesquiaht First Nation and Barkley Project Group;
- Investigation of integration scenarios for two island grids in Haida Gwaii, British Columbia;
- Construction of a cell-scale battery test facility at Pacific Regional Institute for Marine Energy Discovery (PRIMED);
- Collaboration with AOE on the development of air pumping wave energy converter concept;
- Collaboration with Blutility to conduct a simulation-based design study of wave energy converter concept;
- Muchalaht First Nation project, including wave energy FEED study;
- Examination of new model for predicting hydrodynamic forces on point absorber type wave energy converters.

CanmetENERGY/NRCan and National Research Council (NRC)

Marine energy resources atlas for province of BC is completed and can be access at https://www.bc-atlas.ca. This atlas provides a comprehensive assessment of tidal, wave and river hydrokinetic energy resources throughout BC. This was a pilot project and the aim was to make expand this resource atlas for across Canada.

NRCan in continuing collaborative research projects in advancing river hydrokinetic energy with NRC, academia, industry and the Canadian Hydrokinetic Turbine Test Centre (CHTTC). The River Hydrokinetic Energy Resource Assessment project was initiated in 2019 to develop new and improved river hydrokinetic energy (RHE) resources datasets that can be leveraged by utilities, project developers, academia, communities and energy planners. It is conducting a high-resolution assessment at specific sites identified within high-energy river systems within the provinces of Manitoba and Ontario. This will address existing gaps regarding the lack of useful engineering RHE resource data including, but not limited to power density of stream flow, seasonal variability in water flow, water depth, channel width and velocity for specific sites. These data will facilitate investment decisions for technology demonstration for this emerging renewable energy technology.

Demonstration of tidal current and river hydrokinetic energy systems will support technology and project developers to demonstrate tidal current energy (TCE) and RHE systems, resulting in two to five systems deployed by 2025. The project will:

- Demonstrate the technical feasibility and economic viability of TCE and RHE technologies;
- Increase investment confidence for project developers, utilities, independent power producers, and remote communities;
- Increase cost competitiveness of TCE and RHE projects, improving commercialization prospects.

Activities will include monitoring and reporting on the performance of demonstration projects in Canada, performing technical analysis of data in terms of power generation, efficiency and reliability; and validating numerical modelling. This project will also include the assessment of RHE performance, including evaluation of appropriate turbine array spacing. The outcome of these initiatives will support ongoing development of the IEC Standard IEC/TC114 PT 62600-300 Electricity Producing River Energy Converters - Power Performance Assessment.

Technology Demonstration

Projects in the Water

Big Moon Power

Big Moon Power completed another successful summer of prototype testing in Nova Scotia' Bay of Fundy. It marks the final prototype testing done by the developer in the province. Data collected through these tests will be used to work with local engineering firms to finalize the final design drawings for commercial units. These units will be installed in Nova Scotia and grid connected in 2020.

Sustainable Marine Energy (SME)

Sustainable Marine Energy (SME) has continued to ramp up its operations in Nova Scotia following the successful installation of their 280 kW PLAT-I 4.63 demonstrator in Grand Passage, Bay of Fundy in September 2018. The deployment in Grand Passage demonstrated the benefits of floating tidal energy systems, primarily the ease of installation and maintenance access. It has also provided an excellent platform for scientific and research activities which have largely been focussed on performance validation and developing a greater understanding of potential environmental impacts. SME has been working collaboratively with a number of research and academic organisations including Swansea University, Acadia University, Dalhousie University, Nova Scotia Community College (NSCC), Sustainable Oceans Applied Research (SOAR), FORCE, and Offshore Energy Research Association (OERA), and will be building on the work performed over the next year to develop an environmental monitoring system suitable for deployment on its systems at FORCE.

Sustainable Marine Energy's PLAT-I tidal energy platform at Grand Passage, Bay of Fundy, Nova Scotia.

Yourbrook Energy Systems Ltd

Yourbrook Energy Systems Ltd continued testing of its 40 kW prototype in Juskatla Narrows on Haida Gwaii, British Columbia to refine and optimize the pump system and high yield blade performance.

Yourbrook Energy Systems

Planned Deployments

Big Moon Power

Big Moon Power is planning to commence prototype testing in New Brunswick in 2020, allowing the technology to demonstrate its versatility by producing electricity in the world's strongest water resource in the Minas Passage of Nova Scotia and then producing electricity in the reduced tidal resource in New Brunswick. Producing commercial scale electricity from slower moving water will expand the number of potential markets available for Big Moon's technology. The developer is also planning to install and connect commercial units to the grid at its site in Nova Scotia in 2020.

DP Energy

DP Energy was granted $29.75M under the Government of Canada's Emerging Renewable Power Program (ERPP) in 2018 and a 15 year, $530/MWh FIT by Nova Scotia Power for its Uisce Tapa project at the Fundy Ocean Research Center for Energy (FORCE). The project is a 6 turbine, 9 MW array over two berths at FORCE using the Andritz Hammerfest Hydro (AHH) Mk1 turbine. DP Energy has continued to progress the Uisce Tapa project through 2019, completing site specific turbine engineering, undertaken further site characterisation assessments, finalized turbine placement and cable routing as well as developed a high-level Marine Operations plan. It is on track to begin developing onshore works in the second half of 2020, install subsea cable works in the second half of 2021 and lastly install the subsea structures and turbines in the second half of 2022.

Jupiter Hydro

In August 2019, Jupiter Hydro was awarded two permits from Nova Scotia Department of Energy and Mines (NSDEM) for an in-stream tidal energy project in the Bay of Fundy: One allowing Jupiter to test a non-grid connected 1 MW prototype and the other for 2 MW which included the authorization of a power purchase agreement (PPA). Jupiter has begun the process of detailed design with Hatch in September 2019. It is Jupiter's intention to put two 150 kW screws on the full-size swing arms of its tidal device to test and confirm the functionality and efficiency. Jupiter then plans to install two 500 kW screw turbines on the swing arms and test the full-scale units. Jupiter is targeting to deploy its device by fall 2020.

Nova Innovation

Nova Innovation continues to build its team in Canada with staff in Halifax and Ottawa. Over the course of 2019, Nova carried out multiple activities to support its proposed Petite Passage Tidal Project. These included extensive stakeholder engagement, signing of a Memorandum of Understanding with the Municipality of

Digby, applications for various licenses and permits, and mapping of supply chain options. Nova's activities and strategy in Canada are supported by the experience it has gained through international projects. Its Shetland tidal array project has now been successfully operating for over three years and has demonstrated cost reductions for tidal energy including a 15% reduction in LCOE last year.

ORPC Canada

In partnership with both Inuit and Cree communities, ORPC Canada will complete a feasibility study and community outreach initiative for a site assessment of the Great Whale River in Québec. This project is a first step for the evaluation of marine resources and installation of ORPC RivGen® marine renewable energy power systems in this community and in other remote communities in northern Québec and Canada. The project, modelled upon a successful project realized in Alaska by the Igiugig community and ORPC, will provide initial planning for the proposed installation of a clean source of renewable energy for northern communities.

Sustainable Marine Energy (SME)

SME will be developing its 9MW Pempa'q project at FORCE which will be delivered and operated by Spicer Marine Energy, a joint venture between SME and Minas Tidal Ltd. The project will utilise SME's next-generation 420 kW platform, the PLAT-I 6.40. Construction of the first of the platform series will commence early in 2020.

The Pempa'q project at FORCE will be built out in stages that will enable the benefits of incremental technology improvements and operational learning to be captured.

Yourbrook Energy Systems

Yourbrook Energy Systems is conducting investigative work in conjunction with Council of the Haida Nation on its site for the Kamdis Tidal Power Demonstration project in British Columbia. This project is a 500 kW demonstration project through BC Hydro's Demonstration Generator Inter Grid Connection program. Its patented system with a pumped storage component creates firm base load power simplifying the transition between diesel generation and renewable power. The successful implementation of the demonstration project will lead to a scaled up 2-2.5 MW project.

Oneka Technologies

Oneka Technologies has been focused on producing and commercializing autonomous desalination units providing drinking water from the ocean using only waves as an energy source. Its last generation unit produced from 5 to 10 m^3 of fresh water per day depending on the condition and demonstrated that the technology can perform well. Oneka's commercial activities have proven successful, with growing interest from users in Florida, the Caribbean and Chile. Oneka has been developing a new generation buoy that has been improved to reduce the OpEx of the technology and will be launched soon.

Relevant National Events

Opportunities in Offshore Wind & Tidal Energy - Marine Renewables Canada event
14 January 2020, Saint John, New Brunswick

Marine Renewables Canada West Coast Regional Event
Summer 2020, Victoria, British Columbia

Marine Renewables Canada 2020 Annual Conference
3-5 November 2020, Halifax, Nova Scotia

China

Overview

In 2019, the temporary feed-in tariff for tidal current energy project was approved by the National Development and Reform Commission (NDRC). The Ministry of Science and Technology (MOST) released the National Key Research and Development Programme (2019) of 'Renewable Energy and Hydrogen Energy Technology'. The Guangzhou Institute of Energy Conversion (GIEC) started up maintenance of the floating wave energy platform for next test. The National Ocean Technology Center (NOTC) floating test platform had been deployed in the Weihai test site, and the Weihai test site had the ability to provide test services. The Wanshan Wave Energy Demonstration Project launched the construction of wave energy platforms, expecting to be completed and deployed in March 2020.

Supporting Policies for Ocean Energy

National Strategy

In 2018, the Ministry of Natural Resources (MNR) was established. The responsibilities of the new Ministry include overseeing the development and protection of China's natural resources, setting up and implementing a spatial planning system, and establishing a system for paid use of natural resources. The MNR was founded through the merger of the Ministry of Land and Resources (MLR), State Oceanic Administration (SOA) and other departments. As the Ministry in charge of ocean energy, MNR will focus more on the development and management of ocean energy industries in China.

From August to November 2019, the Standing Committee of the National People's Congress (NPC) dispatched an inspection group to inspect and evaluate the implementation of Renewable Energy Law. The Law is enacted in order to promote the exploitation of renewable energy, increase energy supply, improve the energy structure, ensure energy safety, protect the environment, and attain the sustainable development of economy and society in China. For the purposes of the Renewable Energy Law, renewable energy means non-fossil energy, including wind energy, solar energy, hydro energy, biomass energy, geothermal energy and ocean energy. The Law was issued in 2005, and the NPC Standing Committee passed the proposal of modifying the Law in 2009. In December 2019, the inspection group reported the inspection results to the NPC Standing Committee. The report will provide references for improving the renewable energy law in the future.

Market Incentives

The temporary feed-in tariff for LHD tidal current energy project was approved by NDRC in June 2019. LHD tidal current energy project is the first ocean energy project benefit from the temporary feed-in tariff policy, and the price is about € 0.33/kWh.

In order to promote renewable energy industries development, the NDRC, the MNR and other Ministries released the 2019 version of the Catalogue for the Guidance of Green Industries in February 2019. It will replace the old version of the Catalogue. There are 2 items of ocean energy in the new catalogue: 1) Equipment manufacturing for ocean energy, 2) Facilities construction and operation for ocean energy.

Public Funding Programmes

MOST released the National Key Research and Development Programme (NKRDP) of 'Renewable Energy and Hydrogen Energy Technology' in 2018. NKRDP currently funds 3 ocean energy projects, two projects were awarded in 2019 and focusing predominantly on key technique of high-efficiency and high-reliability wave energy conversion, utilization methods and techniques of OTEC. In 2019, MOST released the application guidelines for projects in areas with IEA Cooperation as part of Intergovernmental Scientific and Technological Cooperation Projects. The objectives of the projects are to support collaborative research within the IEA TCPs.

Research & Development

Wave Energy

GIEC Floating Energy Device

Supported by the Chinese Academy of Sciences (CAS) and China Southern Power Grid, GIEC has completed the first open sea test for their floating energy platform. The 260 kW floating energy platform was an upgraded version of the "sharp Eagle" WEC developed by GIEC that focused on islands power supply. The new hydraulic cylinders were installed, with higher corrosion resistant performance and reliability, and new wave energy converters were installed on the upgraded platform. During the open sea test, the GIEC floating energy platform was successfully connected to the remote island power grid through submarine cables, the maximum daily output was over 2000 kWh. GIEC started up maintenance of the floating energy platform from 2019, and the second open sea test will be expected to begin in March 2020.

In order to support offshore aquaculture through supplies of lower cost energy and ancillary products and to contribute to the cost of offshore infrastructure through the development of exportable energy carriers, there are several offshore energy supply systems being researched based on ocean energy in China.

GIEC floating energy platform in open sea test (Installed wave energy 200kW, solar energy 60kW, a desalination facility with daily production of 6 tones water).

Offshore Aquaculture Cage "Penghu"

GIEC successfully built the first semisubmersible offshore aquaculture cage "Penghu". The platform organically integrates wave energy generation, aquaculture, and tourism, which is driven by renewable energy. The first prototype "Penghu" was deployed to open sea test in June 2019.

Wave energy aquaculture cage "Penghu" in sea test (Length 66m, Depth 28m, and Height 16m, 120kW Wave energy, 10,000m3 aquaculture space).

Ocean-Star Wave -Energy Buoy

The Chaohu Silver Ring Navigation Buoy Co. is developing the maritime buoys powered by wave energy, to deliver series solutions for the power supply of marine instruments. The prototype of 50 W wave energy maritime buoy was deployed to open sea test in 2018, and the prototypes of 90 W, 150 W wave energy maritime buoys was deployed to open sea test in April 2019.

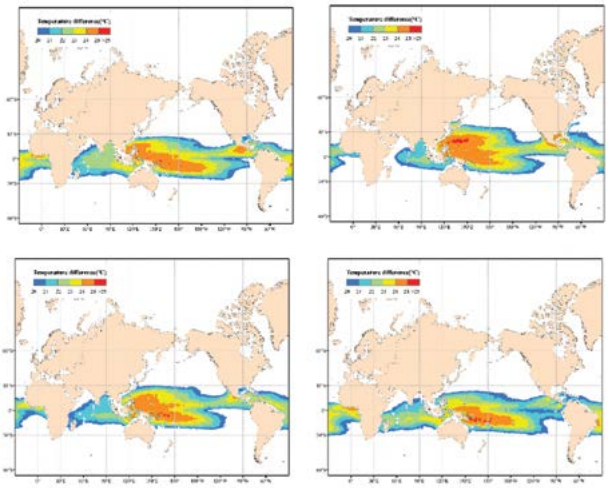
Wave energy maritime buoys in test.

Tidal Current Energy

In recent years, under the support of the National Science and Technology Programmes and SFPMRE, the technology of tidal current energy has been developing very fast in China. There are more than 20 institutes and universities that carry out studies on tidal current energy. The major institutes and universities include LHD Company, Zhejiang University, Harbin Electric Machinery Company, Guodian united power, Ocean University of China, and others. They have developed several sets of tidal current energy prototypes from 60 kW to 650 kW. Most of the prototypes were deployed near Zhoushan Islands to open sea test.

OTEC Resource Assessment

Support by OES and MNR, NOTC is conducting an OTEC resource assessment programme. The objective of the programme, is to support development of OTEC resource, accelerate development of standardized methods for investigation and evaluation, clarify the global OTEC potential, and to provide references for Member Countries. In 2019, The OTEC team of NOTC was completed to prepare the OTEC resource distribution map and the report of Global OTEC Resources Assessment. In next phase, NOTC will discuss the research results with member countries.



OTEC resource distribution

Technology Demonstration

Projects in the Water

LHD Tidal Current Energy Demonstration project

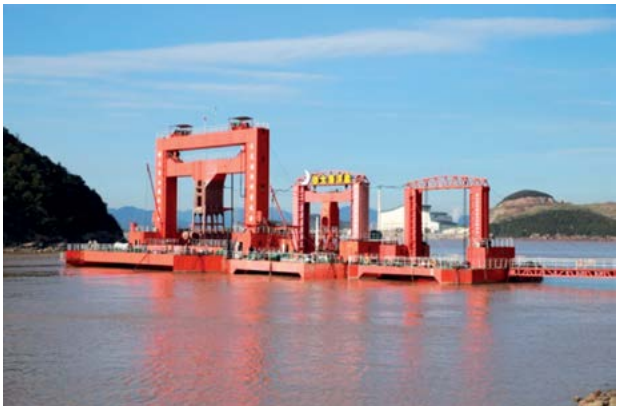
Supported by the SFPMRE, the LHD Tidal current energy demonstration #1 platform was deployed near Xiushan Island in March 2016. Hangzhou United Energy Co. Ltd plan to install 7 turbines in their platform, with installed capacity of 3400 kW. In August 2016, 2 turbines (60 kW, 400 kW) were installed on the platform and successfully connected to the grid. In 2018, 2 turbines (400 kW G-module, 300 kW F-module) were installed on the platform, and the capacity of LHD project reached 1.7 MW. LHD tidal current energy demonstration project has a cumulative power generation exceeding 1.5 GWh since 2016 until September 2019.

Supported by SFPMRE, LHD was funded to press ahead with the next phase project, including a new platform and a 1 MW new turbine. The #2 platform will be deployed near the #1 platform in 2020, and 3 turbines will be installed on the #2 platform in the future.

LHD Tidal Current Energy Demonstration #1 platform

ZJU Tidal Current Energy Demonstration Platform

Supported by the MNR and the MOST, Zhejiang University (ZJU) developed the tidal current energy demonstration platform and deployed near Zhairuoshan Island. From 2015 to 2019, ZJU installed 3 prototypes (60 kW, 120 kW, 650 kW) on the platform for open sea test. As a testing platform for tidal current energy turbines, the demonstration platform has provided installing and testing service for 2 companies.



ZJU Tidal Current Energy Demonstration Platform

NOTC Floating testing Platform

NOTC floating testing platform was deployed in Weihai test site in September 2019. The test platform can provide open sea test for small-scale H-axis turbines and marine instruments. The development of floating test platform symbolizes that Weihai test site had the ability to provide test services.

Planned Deployments

Wanshan Wave Energy Demonstration Project

To further promote the development of ocean energy industry in China, the construction of China's first MW-level wave energy demonstration project was be started with the support of the Ministry of Finance and MNR in 2017. The total project budget is RMB 151 Million. It will make Wanshan become an important base for intensively displaying wave energy technology in China. In 2019, GIEC, China Southern Power Grid, China Merchants Heavy Industry Co. and other units launched the construction of 2 wave energy platforms (500 kW), expecting to be completed and deployed on Wanshan Island to open sea test in March 2020.

Zhoushan Tidal Current Energy Demonstration Project

The Zhoushan tidal current energy demonstration project was developed by the China Three Gorges (CTG) Corporation with the support of SFPMRE. The construction of the demonstration project was be started in 2016, and the total project budget was about RMB 144 Million. In 2019, CTG completed the construction of the 300 kW tidal current energy turbine and will deploy it to open sea test in February 2020. The 300 kW prototype was built by the group including China State Ship Building Corporation, IT Power, Zhejiang University, and others. In the future, the demonstration project can serve as a testing site for tidal current energy prototypes, auxiliary project will be constructed and delivered for use synchronously with the demonstration project.

Construction of Wave Energy Platforms

Marine Renewable Energy Forum 2019

Relevant National Events

Marine Renewable Energy Forum 2019: Hosted by NOTC, was held on 15 October 2019 in Shenzhen, Guangdong Province. The theme was "Creating a New Situation of Marine Renewable Energy". More than 300 government organizations, universities, institutes, companies and stakeholders participated in the forum.

Uk-China Joint Offshore Renewable Energy Conference 2019: Hosted by NOTC, University of Exeter, University of Oxford, etc, was held on 8-9 July 2019 in Qingdao. More than 150 delegates participated in the conference and discussed around development of offshore renewable energy technology. It was followed by the conference where the cooperation agreement between NOTC with University of Exeter was signed.

3rd China-Korea Marine Energy Workshop: Hosted by Shandong University, was held on 9-12 October 2019 in Qingdao. The attendees of the workshop were actively involved in exchange and cooperation in areas such as technology development, academic exchanges, scientific research and management, etc.

Uk-China Joint Offshore Renewable Energy Conference 2019

3rd China-Korea Marine Energy Workshop

Denmark

The Danish Partnership for Wave Power includes nine active wave energy developers of which two have been testing prototypes at sea recently.

Location of the sites in Denmark where Wave energy tests have been carried out. Each site represents wave conditions relevant for the scale of testing.

Overview

The Danish Partnership for Wave Power includes nine active wave energy developers of which two have been testing prototypes at sea recently. Wavepiston completed two-years of testing a 120 m long string of 4 plates activating seawater pumps, at the DanWEC test site facing the North Sea and CrestWing have been testing a large hinged floating wave energy converter "Tordenskjold" in Kattegat.

DanWEC and Aalborg University (AAU) are partners in the Ocean Energy Scale-Up Alliance (OESA) a 3-year project, initiated in January 2019 with 13 partners supported by the Interreg, North Sea Region managed by the Dutch Marine Energy Centre (DEMEC). DanWEC was established as "Greenlab" in 2012 – and the actual test area at Hanstholm was marked in 2015 including two buoys measuring the wave and tidal conditions. Over the years DanWEC has established a thorough knowledge of the wave energy resource and design conditions at the site. In addition, depth contours and seabed material have been mapped. Hub and grid connection are estimated to cost about €5M.

Supporting Policies for Ocean Energy

National Strategy

A strategy and roadmap for wave energy development were presented in 2012 - 2015 by the Partnership for Wave Power. The efforts are ongoing in 2019 to have the strategy implemented within the new Danish government energy plans. The fundamental principles to make wave energy successful are the same that made Danish wind energy technology an international success:

- Financial incentives.
- Guaranteed demand.
- Long-term framework conditions.

Market Incentives

There are at present no dedicated market incentives such as special feed in tariffs for wave energy. The proposal from the Danish partnership is to establish a combination of feed in tariff for a certain energy production combined with lower requirements to private match funding for the projects.

Public Funding Programmes

The main source of Danish funding for wave energy is from EUDP (Energy Technology Development and Demonstration Program). EUDP has funded two wave energy projects in 2019 – Small Scale Smart Power Buoy - Resen Waves and Digital hydraulic PTO for Floating Power Plant.

Compared to more mature energy technologies such as solar and wind, Danish wave power, despite a high success rate of about 30%, only receive a small fraction of the EUDP R&D grants. This is mainly a result of the small number of WEC developers, the capacity of the smaller start-up companies and perhaps the quality of the funding applications.

The impact of the Danish energy research, development and demonstration have been analysed by the Iris Group in 2019. In relation to wave energy technology the analysis states: "*Wave technology has a significant potential*" and "*Wave energy is a young industry dominated by a handful of small entrepreneurial companies developing technologies around TRL 5-7" and "the incumbent industry is awaiting proof of which technologies are working and whether the price of wave energy production can be brought down to a competitive level*" and the conclusion is "*it is important to prioritise if Wave Energy should be tested in Denmark and if funds can be provided to establish relevant infrastructure in Denmark, or if it is equally relevant to implement the R&D efforts in installations and testing in other countries.*"

Research & Development

OES Task 10 WEC numerical models – Status and discussion

EUDP supported in 2018 and 2019, the Danish partners RAMBOLL, AAU, DTU and FPP in the project "OES Task 10" Wave Energy Converters Modelling Verification and Validation. The focus is co-operation verification and validation of numerical models for wave power systems. Ramboll is coordinator on the international part of the OES, where experts from 13 countries participate in the project. The test case for 2019 has been modeling the OWC tested by Kriso.

OES Task 10 Group held workshop in Amsterdam and 11 participants received Travel Scholarship from WECANET and the workshop facilities was supported by OES (https://www.wecanet.eu/oes-task-10-workshop)

IEC Standardisation

On the longer-term Denmark via DS-IEC has for several years been working on standards and guidelines under IEC for wave energy as the basis for the certification when wave energy becomes commercial, like what happened in the wind turbine sector. Denmark has three to four persons on this task.

The Ocean Energy Scale-up Alliance (OESA)

OESA is supported by the Interreg, North Sea Region. The project is managed by the Dutch Marine Energy Centre (DEMEC) and is constructed by "8 Service Providers and 5 Pilots" From the Danish side participates, AAU (Service Providers), DanWEC (Service Provider), FPP (Pilot).

See: https://northsearegion.eu/oesa/about/.

Concrete for Wave Energy

The project "Concrete for wave energy, B2B" supported by EUDP has been carried out in 2019. Co-ordinated by EIC with the participation of Wave Dragon, Development v Kim Nielsen, AAU and HICON. Wave Dragon is an overtopping type converter planned build in concrete with rated power in the 1.5 MW and 4 MW

Concrete for Wave Power – investigating the possibility to include wave power on floating concrete breakwaters.

range, for DANWEC/Canary Islands and Wales/South Africa respectively. The Financing of these full-scale demonstration plants are still a key focus for WD.

More information: https://energiforskning.dk/node/9425.

The KNSwing is multi OWC structure of ship shape also proposed to be built in concrete. As part of this project the possibility to incorporate small OWC chambers in floating concrete harbor breakwaters has been initiated.

Load Control for the Wavepiston Energy Collector

A Eurostars supported project where a consortium of Fiellberg and Wavepiston developed and tested improved load control solutions for the extreme loads during storms. Handling the extreme loads in a simple and efficient way is key to make wave energy competitive, both reducing the CAPEX and OPEX. The project was finalized in 2019.

Floating Power Plant

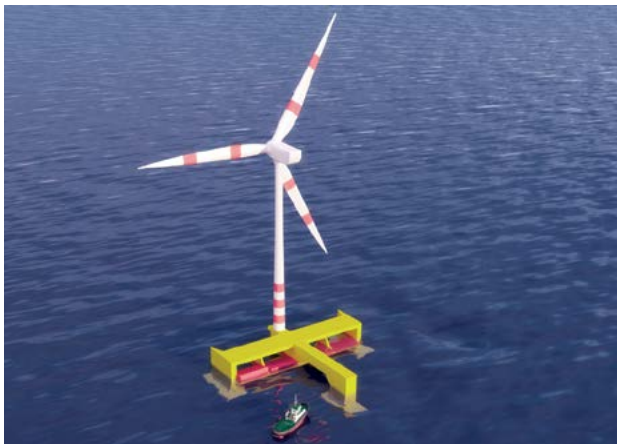
FPP is currently working with consenting and project development in England, Scotland and Ireland with project developer DP energy. A full-scale demonstration project is being developed for Plocan in Spain, designed and validated in using basin and dry tests. FPP participates in number of projects:

- The EUDP supported project adapting FPPs technology to the Oil and Gas Market in partnership with Lundin Norway, APL NOV, Semco Maritime, Cefront, Aalborg university and DNV GL.
- The EUDP supported project which combines the existing PTO, with newly developed PTO control strategies. The digital hydraulic PTO will improve the performance of the PTO system. The project is carried out in partnership with Aalborg University.
- The North Sea Interreg funded project “OESA” focused at accelerating pilot deployment.

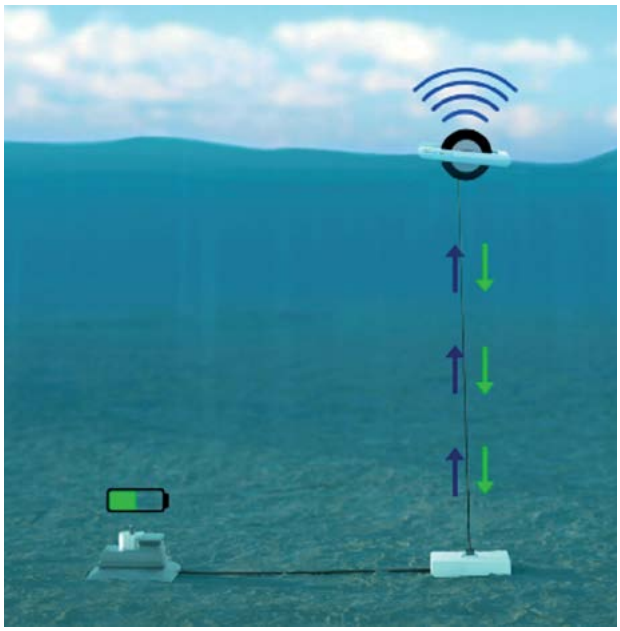
RESEN WAVES

With financial support from EUDP Resen focus on optimization of small 300 to 700-Watt Smart Power Buoys. The project includes both numerical modelling (DTU) and tank testing (AAU). The commercial solution shall supply power and real-time data connection to sensors both on the seabed and the surface where the water depth is below 200 m.

Resen Waves Smart Power Buoy has gone through sea trials for almost 2 years. It has the capability of producing electric power and providing real time access to instruments on the buoy as well on the seabed. Commercial systems are now available for deployment in the oceans.



FPP’s commercial scale technology 2-3.6 MW wave power combined with 6-10 MW wind power.



Resen Waves plug and play solution for Power and Data transmission.

Resen Waves Smart Power Buoy during sea trials

Technology Demonstration

Wavepiston in the North Sea at DanWEC, Hanstholm.

Crestwing in Kattegat.

Projects in the Water

Wavepiston finished in 2019 two years of testing at the DanWEC testsite in Hanstholm. Based on the experience and results Wavepiston will move their tests to PLOCAN, Gran Canaria. At Plocan there is a test platform at sea to which Wavepiston will connect and pump pressurized seawater via a pressure pipe to PTO module placed on to the PLOCAN platform.

Crestwings WEC prototype named Tordenskiold, has been tested over a period of 5,5 months in Kattegat. In May 2019 Crestwings prototype Tordenskiold returned to port for maintenance and improvements after 5,5 months test at sea. The installation has since then been optimized and improved, and the company Crestwing has large expectations for the new test result. In February 2020 Tordenskiold was towed back for further testing in Kattegat. It is the second test period at sea for the installation.

Planned Deployments

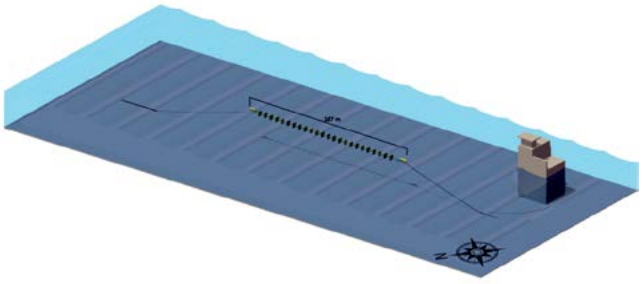
During 2019 the German WEC developer NEMOS received a draft permission from the Danish Energy Agency to start of tests on the Hanstholm site from beginning of 2020 into 2021. NEMOS has been testing their system at Oostende and are part of the Interreg Ocean Energy Scaleup Alliance (OESA) Project.

Wavepiston

Wavepiston is working on two demonstration projects. Demonstration of a full-scale Wavepiston WEC at the PLOCAN test platform in Gran Canaria for conversion to electricity, in 2020 – supported by Horizon 2020 SME Instrument Phase 2. Demonstration of a wave to energy and water system on a tourist island, using the pressurised sea water for both electricity production and desalination via reverse osmosis (produce potable water) in a consortium with Vryhof Anchors (coordinators), Fiellberg and Ener.Med, in 2021.

Exowave

ExoWave is working on a submerged hinged flap and focusing on the development of Wave-to-Water solutions. The development of Wave-to-Energy will be accelerated when the first Wave-to-Water plants are on the market, expected in 2020/21.



Wavepiston WEC at the PLOCAN platform.

Exowave submerged flaps connected to a Windfarm.

European Commission

The European Commission is supporting the development of the ocean energy sector through an array of activities: The Energy Union and the SET-Plan in particular, and the Blue Growth Strategy.

Overview

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

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 new European Commission President Ursula von der Leyen said that she wants Europe becoming the world's first climate-neutral continent by 2050. To achieve this, the European Commission presented the European Green Deal[2]. Part of the European Green Deal will be a marine renewable energy strategy which will be presented in 2020.

New support programmes (Horizon Europe and Innovation Fund) and regulations will be developed.

Supporting Policies for Ocean Energy

European Strategy

The European Commission is supporting the development of the ocean energy sector through an array of activities: The Energy Union and the SET-Plan, in particular, and the Blue Growth Strategy. The 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.

The SET-Plan Steering Committee has endorsed the "SET-Plan Implementation Plan for Ocean Energy[3]" which was developed by a 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 Energy[4]. These targets are a levelized cost of energy (LCOE) of €15c/kWh by 2025 and of 10 cEUR/kWh by 2030 for tidal energy and of €20c/kWh by 2025 of €15c/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 consequently their cost-reduction. In 2019 a working group has been established which will realize the plan. This group is support by the H2020 OCEANSET project.

The European Commission, in the period 2007-2018, has supported a variety of ocean energy projects for a total investment of €864M, 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).

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 "Blue Economy annual report 2019"[5] published in May 2019. 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 report includes a chapter on regional analysis, which provides an overview of the main socioeconomic features of all EU sea basins and examples of smart specialisation.

The "Clean Energy for EU Islands[6]" is a policy initiative, launched in 2017, with the aim of helping islands to

2 https://ec.europa.eu/info/publications/communication-european-green-deal_en
3 Implementation Plan – https://setis.ec.europa.eu/system/files/set_plan_ocean_implementation_plan.pdf
4 Declaration of intent – https://setis.ec.europa.eu/system/files/integrated_set-plan/declaration_of_intent_ocean_0.pdf
5 https://op.europa.eu/en/publication-detail/-/publication/676bbd4a-7dd9-11e9-9f05-01aa75ed71a1/language-en/format-PDF/source-114596948

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). To facilitate the clean energy transition, the Commission launched in 2018 the 'Clean energy for EU islands secretariat'[7], which offers support and assistance on project preparation to Europe's islands communities. The EU Island Facility is a new Horizon 2020 project which has the goal of mobilising more than €100M of island investments in clean technologies by 2023. To achieve this, the project team of NESOI (New Energy Solutions Optimised for Islands) will build on the work of the "Clean Energy for EU Island Secretariat" to foster and deliver bankable clean energy projects.

To meet the EU's energy and climate targets for 2030, EU Member States need to establish a 10-year integrated national energy and climate plan (NECP) for the period from 2021 to 2030. The NECPs were introduced by the Regulation on the governance of the energy union and climate action (EU/2018/1999).[8] The national plans outline how the EU Member States intend to address energy efficiency, renewables, emissions reductions, interconnections, and research and innovation. This approach requires a coordination of purpose across all government departments. It also provides a level of planning that will ease public and private investment. The fact that all EU Member States are using a similar template means that they can work together to make efficiency gains across borders. All the EU Member States were asked to submit their plans before the end of 2019. EU countries are required now to develop national long-term strategies by 1 January 2020, and they must ensure consistency between long-term-strategies and the NECPs.

The new European Commission President Ursula von der Leyen said that she wants Europe becoming the world's first climate-neutral continent by 2050. It will be the greatest challenge and opportunity of our times. To achieve this, the European Commission presented the European Green Deal[9]. It will be the most ambitious package of measures that should enable European citizens and businesses to benefit from sustainable green transition. Measures accompanied with an initial roadmap of key policies range from ambitiously cutting emissions, to investing in cutting-edge research and innovation, to preserving Europe's natural environment.

Supported by investments in green technologies, sustainable solutions and new businesses, the Green Deal can be a new EU growth strategy. Involvement and commitment of the public and of all stakeholders is crucial to its success. Part of the European Green Deal will be a marine renewable energy strategy which will be presented in 2020.

The new European Commission President Ursula von der Leyen said that she wants Europe becoming the world's first climate-neutral continent by 2050. It will be the greatest challenge and opportunity of our times. To achieve this, the European Commission presented the European Green Deal9. It will be the most ambitious package of measures that should enable European citizens and businesses to benefit from sustainable green transition.

Market Incentives

The NER300 programme remains still 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 2019. The table below presents an overview of the project announced and their status.

The Innovation Fund is a new programme under development and will follow up the NER 300 programme. The planning is to launch its first call in 2020. 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).

6 https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/clean-energy-eu-islands
7 https://www.euislands.eu/
8 https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/national-energy-climate-plans
9 https://ec.europa.eu/info/publications/communication-european-green-deal_en

Pre-commercial projects awarded support through NER300

Country	Technology	Project	NER300 Award (€ M)	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 Funding 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.

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 €100B. There is a provisional agreement reached about the main structure of the programme. Final adoption of the programme is expected in 2020.

Projects supported by EIB InnovFin Energy Demo

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

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 €165M for ocean energy R&D to 44 different projects, including feasibility studies under the Small Medium Enterprises instrument.

Horizon 2020 currently funds 19 R&D projects on ocean energy. In 2019, three Horizon 2020 projects were launched. There was also a call on in Horizon 2020 focussing on the set-up of a "European Pre-Commercial Procurement Programme for Wave Energy Research &Development[10]".

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 3GWh 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	Title	Technology developer	Focus	Key Achievement
2019	LiftWEC	Developing Innovative Strategies to Extract Ocean Wave Energy		Development of a new type of wave energy converter using lift forces generated on a rotating hydrofoil	Project started in 2019. No progress/ status update is currently available
2019	Element	Effective Lifetime Extension in the Marine Environment for Tidal Energy	Nova Innovation	Use of Artificial Intelligence to improve tidal turbine performance	Project started in 2019. No progress/ status update is currently available
2019	NEMMO	Next Evolution in Materials and Models for Ocean energy	Magallanes / Sagres	Focus on the development of blades for tidal turbines	Project started in 2019. No progress/ status update is currently available
2018	RealTide	Advanced monitoring, simulation and control of tidal devices in unsteady, highly turbulent realistic tide environments	Sabella, EnerOcean	Identifications of failures caused o tidal turbines at sea whilst providing a step-change in the design of key components such as blades and PTO	Real-time monitoring tools have been installed on the nacelle of the device
2018	Imagine	Innovative Method for Affordable Generation IN ocean Energy	UMBRA-GROUP	Development of a new Electro-Mechanical Generator (EMG)	Design, development and fabrication of a 250 kW EMG prototype
2018	MegaRoller	Developing the PTO of the first MW-level Oscillating Wave Surge Converter	AW Energy	Development and demonstration of a next-generation PTO solution for wave energy converters	PTO technology for a 1 MW oscillating wave surge converters (OWSC)

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

2018	Sea-titan	SEA-TITAN: Surging Energy Absorption Through Increasing Thrust And efficiency	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	Advanced Design Tools for Ocean Energy Systems Innovation, Development and Deployment	Corpower, EDF, Enel Green Power, Naval Energies, Nova Innovation, OceanTEC	Development and demonstration of a 2nd generation open source design tool for ocean energy technologies	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	Second Generation technologies in ocean Energy	Magallanes	To develop a 2 MW pre-marketable floating tidal energy platform	In 2018 the 2 MW device was fabricated and towed to EMEC in preparation for installation
2017	EnFait	Enabling Future Arrays in Tidal	Nova Innovation	To scale up the existing 300 kW tidal array located in Shetland by expanding it to 600-700 kW with incremental addition of 100 kW tidal turbines	Identification of upgrades necessary for the turbines, including condition monitoring tools
2017	OCCTIC	Open-Centre Tidal Turbine Industrial Capability	OpenHydro	To drive the cost of open-centre tidal turbine in par with offshore wind	The project has worked on the optimisation of the open centre turbine focussing on blade and PTO design
2016	FLOTEC	Floating Tidal Energy Commercialisation project	Orbintal	Demonstration of a 2 MW floating tidal energy converter.	The OR2 was deployed at EMEC in 2016, has now generated over 3 GWh of power with capacity factors above 38%. An improved version of the 2 MW devices has been developed
2016	TAOIDE	Technology Advancement of Ocean energy devices through Innovative Development of Electrical systems to increase performance and reliability	Ocean Renewable Power Company	Development of wet-gap generators, Lifetime cost reduction	The project has reached half-way and has now finalised the design of the synchronous permanent magnet generator

2016	TIPA	Tidal Turbine Power Take-Off Accelerator	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	Advanced Braking Module with Cyclic Energy Recovery System (CERS) for enhanced reliability and performance of Wave Energy Converters	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	Multi-Use in European Seas	N/A	Review of existing planning and consenting processes against international quality standards for maritime spatial planning	The project has undertaken an analysis of marine stakeholders in Europe and is currently developing action plan to highlight the potential of Blue Growth in different regions in Europe
2016	OPERA	Open Sea Operating Experience to Reduce Wave Energy Cost	OceanTEC	To collect and share two years of open-sea operating data of a floating oscillating water column wave energy converter	In 2018, the Marmok device developed by OceanTEC was equipped with the new 30 kW turbine developed by Kyamaner, which has been previously successfully validated at Mutriku
2016	PowerKite	PowerKite - Power Take-Off System for a Subsea Tidal Kite	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	WETFEET	Wave Energy Transition to Future by Evolution of Engineering and Technology	OWC Symphony	Investigating the issues of reliability, survivability and high cost of wave energy components	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 Marinerg-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 Programs

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), 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). BLUEGIFT is a €2.5M European Regional Development Fund project that aims to help Atlantic Area companies test the next generation of Marine Renewable Energy (MRE) technology in real sea environments and prove power can be economically generated from the ocean. BLUEGIFT is a €2.5M European Regional Development Fund project that aims to help Atlantic Area companies test the next generation of Marine Renewable Energy (MRE) technology in real sea environments and prove power can be economically generated from the ocean. At the end of 2019, the Interreg Project TIGER was launched. The project is supported by the European Regional Development Fund (ERDF). The aim of the project is to drive the growth of tidal energy across the English Channel (UK and France) by supporting deployment of tidal energy devices.

Relevant Publications

SETIS Magazine

https://setis.ec.europa.eu/publications/setis-magazine/ocean-energy

2018 Ocean Energy Technology Development Report

https://setis.ec.europa.eu/publications/relevant-reports/ocean-energy-technology-development-report

2018 Ocean Energy Technology Market Report

https://setis.ec.europa.eu/publications/relevant-reports/ocean-energy-technology-market-report

France

In 2019, the French regulatory framework was secured in order to facilitate and accelerate the deployment of the entire spectrum of Offshore Renewable Energy (ORE) technologies, thus creating an obvious impetus for Offshore Wind, without neglecting the remaining Ocean Energy sectors.

Overview

In 2019, the French regulatory framework was secured in order to facilitate and accelerate the deployment of the entire spectrum of Offshore Renewable Energy (ORE) technologies, thus creating an obvious impetus for Offshore Wind, without neglecting the remaining Ocean Energy sectors. At any given time, up to 5 tidal turbines located on demonstration sites were concurrently delivering power to the grid, providing solutions suitable for various economic paradigms. French developers working on wave energy conversion, OTEC, salinity gradient and hybrid systems, although representing lower TRLs, are also tending to prove their assets in the local energy mix for non-interconnected sites or for alternative usage rather than just providing electricity. There is also evidence of a fast-growing community of engineers, researchers and skilled professionals that firmly supports the deployment of ORE in the country.

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, is planned to be updated in 2020, and every 5 years thereafter. Separate but comparable documents are defined for the mainland as well as oversea regions and territories. In the present document, which is currently under public consultation, distinct and ambitious figures of installed capacities and timing for calls for tenders are given for both bottom-fixed and floating offshore wind energy. However, for ocean energies, objectives remain 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 last two years, a set of laws and decrees have been enacted supporting renewable energies by simplifying their deployment, namely, for offshore renewable energies:

- Most of the legal obligations (preliminary technical studies, initial environmental assessment, public participation) are performed upstream of the actual permit issuance, thereby considerably reducing the risk for project developers;
- This process is secured as long as the technical details of the project do not diverge from the initial plan, an "envelope permit" being issued allowing technological flexibility if developers have provided an impact assessment based on the worst-case scenario;
- For commercial farms, the cost of the export cable is to be supported by the French Transmission System Operator, which also takes over more legal and financial responsibilities with respect to the availability of electricity exportation.

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) was completed in 2019, and macro-zones suitable for the deployment of offshore renewable energies (wind and tidal) have been delineated: these zones are large enough in order to optimize the location of the areas proposed for future calls for tenders with respect to technical performance and consenting. These zones are in turn large enough to allow optimization of the actual farm layout by the developers.

Market Incentives

Although an incentive programme had awarded 2 demonstration pilot farms of tidal energy converters with partial support, allowing these projects to benefit from a feed-in tariff (€173/MWh), grants and reimbursable loans, both projects are now on hold in the Alderney Race. This demonstrates that the initial support scheme was not considered supportive enough for the developers. However, new consortia are lining up for 2020 demonstrations in the Alderney Race (e.g. HydroQuest- see below).

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

Public Funding Programmes

The "Investment for the Future" program 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.

The 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 components and prototypes to pilot farms. An estimated cumulative budget of this overall support, strictly for Ocean Energy (excluding floating offshore wind) in 2019 is €68M, which includes 6 large completed or ongoing projects.

Two notable new projects have been co-founded in 2019 for €7,6M: a multi-energy system, the Phares project, enabling the non-grid connected Ushant island to primarily rely on a mix of tidal, wind, solar and battery storage, with a thermal plant as back-up; and an original salinity gradient energy converter for desalination plants, the Sarbacanne project. Awarded funds by the 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 from previous years also involve ocean thermal energy converters, wave energy converters, tidal turbine prototypes and technological bricks such as subsea connectors or hubs, foundation concepts, specific dredging or installation tools, etc.

In 2019, the ANR officially appointed one of the seven "Institutes for the Energy Transition" to be dedicated to marine renewable energies, thus contracting with France Energies Marines (FEM) and dedicating €4M over 2019 and 2020 to innovative research and development projects. This support for public-private collaborative R&D projects helps tackle technological bottlenecks and environmental issues. In all, and over the period 2015-2020, the government will have awarded €16M of R&D co-funding through this program (projects are supported by industry with an equivalent sum).

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 (Pays de la Loire region), 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 quickly be brought to market.

Research & Development

Collaborative projects of the Institute for the Energy Transition FEM

France Energies Marines supports collaborative OE R&D projects with the support of ANR. Following is a list of selected projects running in 2019, producing data, software and publications:

DiME	Dimensioning and met ocean: modelling and observations of extreme sea states for OE
THYMOTE	Wave and bottom friction induced turbulence and assessment of sediment transport in the Alderney Race
HYD2M and PHYSIC	A bibliographical atlas of biofouling over the French coastlines, including overseas
ABIOP+	In service health monitoring of OE moorings to anticipate failures
MHM-EMR	Seafloor cable stability and hydrodynamics in strong tidal currents
STHYF	Submarine power cable interactions with environment
SPECIES COMEEET	National panel of experts offering recommendations on environmental and socio-economic issues related to OE
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 OES
INDUSCOL	Monitoring of durability of glued multi-material structures (tidal blades)
DUNES	Dynamic and impact of hydraulic dunes on MRE projects
LISORE	Design of subsea or floating substations for tidal farms

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

Since 2016, this program has cumulated €6M of awarded funding for projects dedicated to local academic teams in conjunction with industrial stakeholders. More than 20 projects have been operated covering a broad range of topics, with the following applicable to OES:

ECOSFARM	Generic control-command tool for testing operating strategies of tidal farms
FRYDOM	Flexible and rigid body dynamic modelling for marine operations
DYNAREV, ECHOSONDE, LEHERO, TOCCME	Marine growth and environmental characterizations
CEAUCOMP, FIRMAIN	Ocean energy material ageing
OMCEND, BRAGGMETER	Structural health monitoring
AMM-EMR	Advance mooring monitoring
ORIGAMI and R-COONECT	Electrical connexion

Easing access to European networking and expertise through OPIN, MEA and Ocean Demo

WEAMEC has a key role in the development of the Ocean Power Innovation Network (OPIN), a European collaborative network funded by Interreg North West Europe from 2019 to 2021. The network boosts both cross-sectoral and cross-regional collaboration between Offshore Renewable Energy actors. In 2019, OPIN members could access free services such as 6 networking events organized in France, Ireland, UK and the Netherlands, as well as technology assessments and support for travel.

Ecole Centrale de Nantes (ECN) and INNOSEA participate in a complementary programme, the Marine Energy Alliance (MEA), which aims to progress the combined technical and commercial maturity level of 40 SMEs by delivering a suite of bespoke integrated technical and commercial services.

Easing access to test sites and tanks: THeoRem, Marinet2, Marinerg-I, OceanDemo, Foresea and BlueGift

The Research Infrastructure THeoREM, which brings together ECN and IFREMER hydrodynamics testing facilities, will enlarge its scope of activity in the near future with the integration of the IFSTTAR material and geotechnical testing facilities. A major objective of THeoREM is to become the French node of the future MARINERG-i ERIC aiming at developing and supporting research for the development and deployment of Offshore Renewable Energy. The objective of this Distributed Research Infrastructure is to allow the sustainability of experimental research activities for the development and deployment of OE technologies undertaken in the MaRINET (FP7) and MaRINET2 (H2020) projects. For the latter, IFREMER coordinates the trans-national access program.

Since 2016, the SEM-REV wave and floating wind test site of ECN is involved in the Interreg projects Foresea, OceanDemo and BlueGift which aim to help bring ocean energy technologies to market by providing access to Europe's world-leading network of test centres. Through these projects, the performance of innovative ocean renewable energy technologies is demonstrated in real sea conditions, helping to leverage the investment needed to take new products to market.

SEENEOH, the estuarine tidal test site running in Bordeaux, also belongs to the set of test sites whose access is facilitated for SMEs thanks to the OceanDemo and BlueGift Interreg projects.

Conformity assessment made easier with Met-Certified

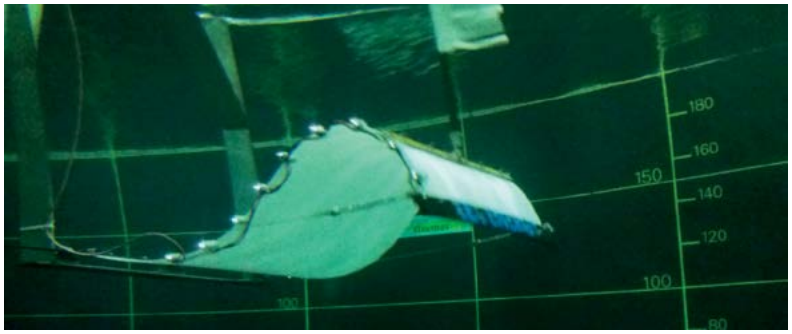
Conformity assessment can mitigate technical and financial risks of technologies, which in turn attracts finance and encourages international trade. As marine energy is an emerging industry, international standards are yet to be consistently adopted and a conformity assessment system is currently under development. Met-Certified (Marine Energy Technologies – Certified) is an Interreg 2 Seas funded project which aims at accelerating the development of standards and certification schemes under the umbrella of the International Electrotechnical Committee (IEC). The project enables the application of IEC technical specifications 62600 for marine energy convertors to pilot projects during tank and open sea testing and provides feedback to the committees that develop and maintain the specifications. The French contribution is supported by IFREMER as a partner and 4 entities as observers (BV, Eel, GICAN, Exceedence), with OES participating as an observer as well!

Improvements in OTEC technology, Deep sea conversion

Deep sea conversion plants aim to use the benefits of deep seawater for multiple uses. Starting from an ocean thermal energy conversion system, designed to produce electricity, other technologies can be added, such as SWAC (Sea Water Air Conditioning), desalination (drinking water), industrial cooling, or even aquaculture.

Since 2012, on the Réunion island (Indian ocean), an onshore OTEC prototype has been set up in collaboration between Reunion Island University and Naval Energies. Tests have been running on the energy production system in order to validate the performance of the system and qualify the equipment. Launched in 2019, the European Oceanera-Net Innotex project aims at developing innovative heat exchangers, falling film evaporators and condensers.

In 2019, Naval Energies also carried out biofouling tests in a partnership with IFREMER in La Martinique in order to qualify different preventive solutions (electro-



1/20 scale membrane prototype of the Eel tidal converter tested in the Ifremer flume of Boulogne/mer

chlorination, ozonation, biopolymers) and curative treatments (biocide and mechanical) thanks to its biofouling test bench. The objective is to maintain the long-term thermal performance of OTEC heat exchangers in representative conditions and to identify the most efficient solution with the lowest energy consumption and the lowest environmental impact. These investigations demonstrated the long-term efficiency of these treatments in limiting biofouling which has already set the stage for future savings in CAPEX/OPEX.

Test bench facilities La Réunion Island

Technology Demonstration

Projects in the Water

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

At the **SEM-REV test** site on the Atlantic coast offshore Le Croisic run by ECN and dedicated to wave and floating offshore wind:

The Wavegem platform is a hybrid (wave, solar) autonomous energy production platform which is designed to supply marine or island installations without access to the electricity grid, providing a source of electricity respecting the environment. Wavegem is designed by GEPS Techno. The platform derives its energy from waves by converting the movements of the float into electrical energy through a closed loop circulation of seawater employing a low speed turbine. PV solar panels also cover the platform which was installed on the SEM-REV site on 21 August 2019, kicking off 18 months of offshore testing. The platform is secured with a four-point synthetic mooring system. The device joins FLOATGEN, the floating wind turbine demonstration, on site since Spring 2018.

In addition, in the framework of the Foresea project mentioned above, instrumentation and subsystems for OE are also being tested underwater. Presently being tested are cable cast iron shells with iBOCS (FMGC).

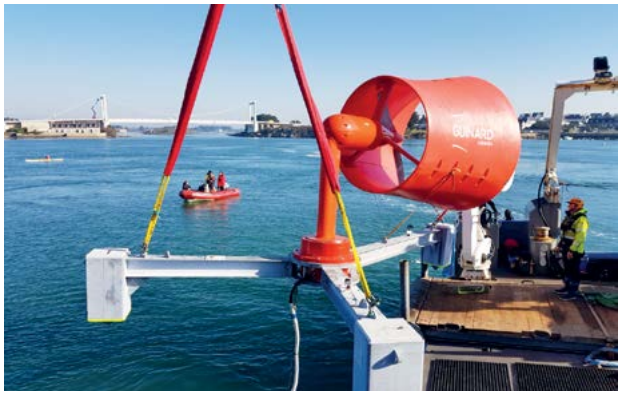
At **Paimpol-Bréhat** in the Channel, run by EDF and dedicated to tidal converters:

The OceanQuest tidal turbine was successfully installed and connected and has already reached the milestone of 6 months of continuous operation. This 1MW machine with 2 vertical axis turbines designed by Hydroquest has been manufactured and fully assembled by CMN's teams in Cherbourg.

In the **Etel** river estuary in Brittany, the Guinard Energy P154 turbine (20 kW) was installed on a gravity foundation in February 2019. Integrated into a hybrid system with PV panels and battery storage, the full system has been grid connected since April. Another

Wavegem hybrid wave-solar platform and Floatgen floating offshore wind turbine currently being tested at SEM-REV (ECN credit)

OceanQuest 1MW tidal turbine immersed at Paimpol Bréhat in April 2019



P154 and P66 Guinard turbines, in Brittany and in Guyana

smaller version, the P66 turbine belonging to a floating hybrid system, began a 2-year test on an isolated scientific base in French Guyana (not grid connected) in December 2019.

At **Ushant** island, which is not connected to the mainland grid, and after an operating period of the Sabella D10 tidal turbine since October 2018 as part of the European ICE project, the technical team focused on testing new control methods at the beginning of 2019. In parallel, a defect was detected in the nacelle's cooling system that allows the various components integrated into the nacelle to be cooled. This defect did not prevent the operation of the turbine but rather limited its operating conditions due to the possible rise in temperature of the components which could potentially cause greater damage on the electrical chain. In April 2019, Sabella therefore seized the opportunity of the nearby presence of Olympic Zeus and chose to retrieve its turbine for a maintenance operation.

Sabella D10 on board the Olympic Zeus after lifting offshore Ushant island in April 2019

Planned Deployments

Wave energy converters

SBM Offshore aims at testing offshore the port of Monaco its S3 WEC (around 1 MW) which is a flexible floating 1 m diameter hose made of piezoelectrical material. The wave induced motion of an internal fluid alternately increases and releases circumferential strains in the constitutive rings of the hose, which in turn generate electricity.

Tidal energy converters

The new generation of Hydroquest Ocean tidal turbines will reach a nominal power of 2.5MW. Initial installation is planned in a 10 MW pilot farm in the Alderney Race, Normandy.With the aim of demonstrating the availability of renewable energy solutions for Ushant, an insular community of 2000 inhabitants, the Phares project will combine two Sabella D12 turbines (12 m diameter), a wind turbine, a PV solar plant and storage capacity to be operational by 2021. The enterprise Akuo Energy is developing the overall architecture of this project's renewable and distributed power supply system.

OTEC, Deep Sea conversion

The Bois Rouge eco-technoport on Reunion Island is a major project in deep sea conversion: renewable electricity production using ocean thermal energy conversion technology, air-conditioning, industrial cooling, aquaculture, desalinisation and bottling of drinking water, and production of cosmetics. The Bois Rouge eco-technoport is the first project to use deep seawater in so many applications simultaneously. Naval Energies provides its expertise in electricity production with ocean thermal energy conversion and, more broadly, its ability to extract value from deep seawater with its Deep-Sea Conversion plants.

Relevant National Events

Seanergy is an international forum dedicated to Offshore Renewable Energy and taking place yearly in France. The 2019 event in Dunkirk attracted around 200 exhibitors and more than 2500 international actors from the sector (politicians, utilities, developers, technological experts, NGOs, researchers, investors and subcontractors) around an exhibition area, conferences, business meetings and technical visits highlighting existing novelties implemented in the region. The next edition of Seanergy will take place in Nantes and Saint-Nazaire on 9-12 June 2020.

The French academic system offers several opportunities to study and gain ocean energy skills, particularly at the level of the master's degree:

- Since the 1st class in 2011, ENSTA Bretagne in Brest hosts the advanced Master for marine renewable energies expert;
- Since 2018, ECN in Nantes is partnering in the Erasmus Mundus joint Master degree in Renewable Energy in the Marine Environment (REM) with 3 other European universities.

Germany

Energy Policy & Market Update

In 2019 electricity from renewable energy in Germany again saw new record production levels with a share of almost 43% of electricity consumption - generating more electricity as coal for the first time. However, the renewable energy production capacity increase has slowed down significantly in 2019 with around 1 GW wind onshore and 1.1 GW of new offshore wind capacity for the first time more than onshore. This is the lowest value for onshore wind since the year 2000. In order to achieve the targeted renewable share of 65% in 2030 an added capacity of around 5 GW/a would be necessary. The new PV capacity of around 4 GW added in 2019 brings the total up to almost 50 GW in the country (sources: Bundesnetzagentur.de, Agora-Energiewende.de).

The average tender results for solar power declined again in 2019 after a rise in 2018 to an average of 4.9€cent/kWh. For onshore wind the latest contracts are at 6.2€cent/kWh.

Germany's greenhouse gas emissions fell again by around 50Mt mainly due the reduced production from coal fired power plants and are now 35% below the 1990 level. Meanwhile, CO2 emissions from the buildings and transport sectors have risen due to an in-crease in oil and gas consumption. The decline in CO2 emissions can be attributed to the higher CO2 prices in the EU ETS, a significant increase in renewable generation and lower electricity consumption (source: The energy transition in the power sector – state of affairs 2019. Agora-Energiewende.de).

At the start of 2019, the Commission on Growth, Structural Change and Employment tabled its proposals for the phase-out of coal-fired power plants in Germany. According to these proposals, all coal-fired power plants are to be taken offline by 2038.

At the end of January 2019, the Federal Sectoral Planning for the first section of the 'Ultranet' electricity highway in Hesse and Baden-Württemberg was completed. This marked an important step in the process of expanding the grid. The planning sets out the exact corridor in which the power line will run. 'Ultranet' is one of the five main German power highways and is designed to transport the wind power produced in northern Germany to the south. The project is the first in Germany to put a DC line and an AC line on the same pylons. At the beginning of April 2019, the Bundestag finally gave the go-ahead for the revised Grid Expansion Acceleration Act (NABEG). This act is to make approval procedures for the construction of new power lines in Germany faster and simpler.

In July 2020, Germany will take on the Presidency of the Council of the European Union. The Federal Ministry will then also be responsible for the 'Council for Energy'. From January 2020, Germany will additionally assume the presidency of the North Seas Energy Cooperation, which consists of ten European countries and the European Commission. They are all working together to develop offshore wind energy and the grid infrastructure at the sea. The German expansion target for 2030 for offshore wind power will be raised from 15 to 20 GW.

The new European Commission started work at the beginning of December 2019. The area of energy is to play a key role in the success of the European Green Deal announced by the Commission. An important task will be to evaluate the National Energy and Climate Plans (NECP) of all EU member states. The NECPs contain the countries' national energy and climate policies for a period of ten years. The goal is to raise the share of renewables in final energy consumption to at least 32% and improve energy efficiency. In addition, primary energy consumption is to be cut by at least 32.5% (Source: Federal Ministry for Economic Affairs and Energy. bmwi-energiewende.de).

Ocean Energy 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.

Tidal power developer SCHOTTEL HYDRO with its partner Sustainable Marine Energy (SME) are continuing the sea trials of the "PLAT-I 4.63" prototype at Grand Passage in the Bay of Fundy, Canada. The floating trimaran platform is rated at 280kW and carries four of SCHOTTEL's Instream Turbines "SIT" with 6.3 m rotor diameter. The company has applied to Nova Scotia's Department of Energy and Mines for a marine renewable energy demonstration permit, including the grid connection of said prototype in spring of 2020 and the deployment of an additional next generation unit in mid-2020. The new "PLAT-I 6.40" platform will be equipped with six SIT tidal turbines with 4m rotor diameter, rated at 420 kW in total. Later in 2020 the new platform will be deployed at the Fundy Ocean Research Center for Energy (FORCE) in Nova Scotia, Canada, as the first unit of a 1.26 MW floating array project. This will be the first phase of the 9 MW "Pempa'q" Tidal Energy project at FORCE.

In support of further tidal turbine development in connection with the integration into a PLAT-I floating platform, SCHOTTEL HYDRO is currently conducting a research project called "Optimization of a Floating Turbine System for Harnessing Tidal Energy". Partners are Potsdam Model Basin (SVA), Fraunhofer IEE, 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. As part of this project, lessons learned during field-testing of "PLAT-I 4.63" fed into the design of the next generation power take-off system. The new power take-off system is currently under manufacturing and will undergo sub-component testing in the lab as well as field-testing at Grand Passage during 2020. The project will conclude in spring of 2021.

Wave power developer NEMOS GmbH has successfully started testing its recent wave energy converter (WEC) prototype in Ostend, Belgium. Following a series of handling and installation tests, the machine was finally deployed off the coast of Ostend in October of 2019, near the previously installed NEMOS research tower structure. The beginning of the field-testing phase concludes the related joint project "Design, Manufacturing, Installation and Commissioning of NEMOS Wave Power Plant Model at 1:1 Scale", conducted by NEMOS together with Uni Duisburg Essen, the Development Centre for Ship Technology and Transport Systems, Schaeffler Technologies AG and LIROS GmbH.

PLAT-I 4.63 platform with two turbine arms in maintenance position (source: SCHOTTEL HYDRO)

NEMOS WEC 2019 prototype floater deployed close to the NEMOS research tower (source: NEMOS, Cornelius Weikert)

The 2019 WEC prototype features an 8x2m floater which is connected to a 16m long substructure via a spring-loaded belt drive. The prototype is a standalone floating design and does not require a fixed structure like the initial NEMOS concept.

Furthermore, NEMOS is currently testing a scaled model of a multi-body WEC at the Development Centre for Ship Technology and Transport Systems (DST) in Duisburg, Germany, in connection with the Space@Sea joint project.

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 prolonged until July 2020. In the course of the project the two WEC modules installed at a breakwater at the port of Heraklion, Greece, were technically upgraded to become third generation devices rated at 18kW each. Furthermore, two additional fourth generation devices with slightly larger floaters but doubled power rating were deployed in September 2019. For 2021, SINN Power plans to build and test a floating WEC array comprising of 21 modules with an overall capacity of 0.75 MW approximately 1 km off the coast. A previously announced plan was to deploy such an array at an organic shrimp farm on the island of São Vicente, Cape Verde.

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.

NEMOS designed WEC scale model at DST's wave tank (source: Space@Sea)

Third (left) and fourth generation SINN Power WECs at the port of Heraklion, Greece (source: SINN Power)

India

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. Stakeholders desirous of utilizing Ocean Energy are invited by MNRE for demonstration projects of proven technologies under the Research, Design, Development and Demonstration (RDD&D) policy of the Ministry.

Market Incentives

The Ministry of New and Renewable Energy (MNRE), Government of India, has now accorded ocean energy such as tidal, wave, OTEC, the status of renewable energy for the first time to attract stakeholders in this area. Thus, it shall be eligible for meeting the non-solar Renewable Purchase Obligations (RPO).

Public Funding Programmes

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

Research & Development

Wave Energy

Continuing the ongoing development on OWC based floating wave energy device, experimental studies on OWC performance in wave flume and power module performance in open sea trial have been carried out. Both, unidirectional impulse (UDI) and bidirectional impulse (BDI) turbines have been tested and evaluated. In joint collaboration with IIT Madras, the design for 1 kW and 5 kW BDI turbines has been completed.

Energy from ocean thermal gradient

Experiments have been carried out in the laboratory at NIOT for the assessment of various components of Open cycle OTEC and LTTD system. In these experiments, parameters like turbine speed, pressure losses and electric power output, etc, have been measured and performance of power module and other components were evaluated.

Technology Demonstration

Projects in the Water

The wave powered navigational buoy has been operating for several months continuously in the navigational channel off Kamarajar Port, Chennai.

Planned Deployments

As per request from Andaman & Nicobar (A&N) UT Administration, 4 wave powered navigational buoy will be fabricated and deployed at ports in A&N islands with funding from A&N Administration.

Relevant National Events

An *International Conference on Renewable Energy & Water* (INDACON-19) was organized at NIOT on 7-8 March 2019 with joint collaboration from Indian Desalination Association (InDA) and IEEE-Oceanic Engineering Society.

A workshop on “Renewable Energy from Ocean: Potential along Indian Subcontinent” was organized by IIT-Bombay on 30 September - 1 October 2019.

International Conference on Renewable Energy & Water (INDACON-19)

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. Ireland also recognises that it must significantly step up its commitments to tackle climate disruption and with that in mind launched the Climate Action Plan in 2019.

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. Ireland also recognises that it must significantly step up its commitments to tackle climate disruption and chart a course towards ambitious decarbonization targets. There are three actions that are specifically relevant to the development of offshore renewables.

Development of Irish technologies such as Ocean Energy Ltd's, OE Buoy were also greatly progressed in 2019. The OE Buoy befitted from a blend of Irish and US public funding to complete the build of its 500kW machine in Vigor ship yards in Oregon USA. The buoy was transported for testing in Hawaii in November 2019 and testing is due to commence in 2020. Two EU supported projects (OPIN and OceanSET) also kicked off in 2019 which will significantly contribute towards supports of the wave and tidal sector.

Supporting Policies for Ocean Energy

National Strategy

Climate Action Plan

In 2019 the Department of Communications, Climate Action and the Environment launched the Climate Action Plan in response to the climate disruption which is already having diverse and wide ranging impacts on Ireland's environment, society, economic and natural resources. The plan is not limited to offshore renewables, but the intention of the plan is to increase energy output of offshore renewables from 25 MW to 3.5 GW by 2030. The actions relevant to offshore development in the Climate Action Plan are:

- Action 25: Facilitate the development of Offshore Wind, including the connection of at least 3.5 GW of offshore wind, based on competitive auctions, to the grid by 2030. We will establish a top team to drive this ambition.
- Action 26: Support the ocean energy research, development and demonstration pathway for emerging marine technologies (wave, tidal, floating wind) and associated test infrastructure.
- Action 27: Support innovation enterprise hubs and the supply chain for offshore renewable energy.

Each action has specific and targeted sub-actions with responsibility and timelines identified; to ensure delivery.

While action 25 specifically mentions offshore wind; the sub-actions will also benefit the offshore wave and tidal technologies via the delivery of a comprehensive and streamlined consenting regime, strengthen the grid to enable an increase of offshore renewables and establish an incentive scheme for power purchase of offshore renewables. The realisation of these actions will significantly progress the development of any offshore technology in Ireland.

The Offshore Renewable Energy Development Plan (OREDP)

In 2014 the Department of Communications, Energy and Natural Resources (DCENR) published the Offshore Renewable Energy Development Plan (OREDP) (http://www.dcenr.gov.ie/energy/en-ie/Renewable-Energy/Pages/OREDP-Landing-Page.aspx). The OREDP, 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 OREDP is seen as providing a framework for the development of this sector.

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.

This plan was reviewed in 2017 and was subject to a full public consultation. The final report of the review was published in May 2018 and can be viewed here OREDP Interim Review May 2018. This review does not make any changes to the OREDP; rather it charts the progress on the plan, identifies challenges that have emerged and areas that need to be prioritised or require attention. The plan is due for a detailed review in 2020 and will build on the actions of the Climate Action Plan.

Market Incentives

The proposed new Renewable Electricity Support Scheme (RESS) will provide support to all renewable electricity projects in Ireland. There will be a primary focus on cost effectiveness, however the RESS will also deliver on broader range of policy objectives, including:

- An Enabling Framework for Community Participation through the provision of pathways and supports for communities to participate in renewable energy projects.
- Increasing Technology Diversity by broadening the renewable electricity technology mix (the diversity of technologies).
- Delivering an ambitious renewable electricity policy to 2030.
- Increasing energy security, energy sustainability and ensuring the cost effectiveness of energy policy.

RESS auctions will be held at frequent intervals throughout the lifetime of the scheme. This will allow Ireland to take advantage of falling technology costs and by not auctioning all the required capacity at once; we will not be 'locking in' higher costs for consumers for the entirety of the scheme.

The Scheme will provide for a renewable electricity (RES-E) ambition of up to 70% by 2030, subject to determining the cost-effective level which will be set out in the draft National Energy and Climate Plan (NECP).

RESS auctions will be designed in line with trajectory targets identified in Ireland's NECP. The first RESS 1 auction will take place within the timelines set out in the Climate Action Plan and assisting in the early delivery for our trajectory to 2030.

The first auctions are due to commence in 2020. All information on forthcoming auctions can be viewed online at https://www.dccae.gov.ie/RESS.

Public Funding Programmess

SEAI has supported Ocean Energy research and development with over €20M in Government funded grant support provided to Irish SME's to develop their technologies. Since the support began in 2003, SEAI has funded 125 projects of which 113 were funded through Prototype Development Fund.

SEAI Prototype Development Fund

In 2009, SEAI launched the Prototype Development Fund (fund). The fund was the first grant programme solely dedicated to offshore renewable energy in Ireland. To date the fund has supported 113 projects with more that €18M grant funding given to Irish SME's. 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. The scheme closed in January 2019 for review, however opportunities for funding was maintained for the wave, tidal and floating wind sector through the SEAI Research, Development and Demonstration fund.

SEAI Research, Development Demonstration Fund

The SEAI National Energy Research Development and Demonstration (RD&D) Funding Programme invests in innovative energy RD&D projects which contribute to Ireland's transition to a clean and secure energy future. The key programme objectives include the following:

- Accelerate the development and deployment in the Irish marketplace of competitive energy-related products, processes and systems.
- Support solutions that enable technical and other barriers to market uptake to be overcome

- Grow Ireland's national capacity to access, develop and apply international class RD&D.
- Provide guidance and support to policy makers and public bodies through results, outcomes and learning from supported energy projects.

The call included two focussed ocean energy topics as well as one open topic. SEAI received 18 applications relevant to the offshore renewable energy sector; nine were successful in their bid for funding. Information on the successful projects: https://www.seai.ie/data-and-insights/seai-research/research-projects/.

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. Six projects with nine Irish partners were approved in the two OCEANERA-NET joint calls over the course of the programme. The last of these projects were successfully completed in 2019.

Ocean Energy ERA-NET Cofund

The Ocean Energy ERA-NET Cofound (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.

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. A second call was issued in 2019. Contracts for projects are currently being negotiated.

Pre-Commercial Technology Fund

In 2019, SEAI were part of a European consortium to explore options to set up a European Pre-commercial programme, equivalent to the national programme that Wave Energy Scotland (WES) manage in the UK. Although the bid for EU funding was successful, SEAI did not manage to secure national funding for the project and as a result have stepped back from the project.

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Research & Development

MaREI, the SFI Research Centre for Energy, Climate and Marine

MaREI is the Science Foundation Ireland (SFI) Research Centre for energy, climate and marine, coordinated by the Environmental Research Institute (ERI) at University College Cork. MaREI has over 200 researchers across 12 partner institutes in Ireland working with over 50 industry partners focussing on the energy transition, climate action and the blue economy. MaREI delivers excellent research with societal impact by supporting industry, informing policy and empowering society.

MaREI's research capabilities cover a wide range of cross-cutting topics in marine renewable energy technologies, materials and structures, observation and operations, coastal and marine systems, bioenergy, energy policy and modelling, and energy management. MaREI researchers work with collaborators in more than 36 countries and this research increasingly underpins energy and climate policies of the Irish Government and the European Union. Through engaged research and dialogue with stakeholders and communities, MaREI also supports the human and societal dimensions of climate action and marine conservation.

The research team comprises internationally recognised experts in energy, climate and marine from University College Cork, University of Limerick, NUI Galway, Maynooth University, University College Dublin, Cork Institute of Technology, Trinity College Dublin, Dundalk Institute of Technology, Technological University Dublin, The Dublin Institute for Advanced Studies, Tyndall National Institute, and the Economic and Social Research Institute.

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 have 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:

- **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.
- **H2020 INFRADEV 2016-2019 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.
- **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.
- **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 – Finished June 2019.
- **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.
- **H2020 LiftWEC** has the objective of developing a new type of wave energy convertor. Irish Partners are MaREI-UCC and MaREI- MU (led by QUB).
- **H2020 MUSICA** projects involves the deployment of a hybrid renewable energy platform in the Mediterranean. Irish Partner is MaREI-UCC.
- **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-UCC.
- **INTERREG AA PORTOS** project works on developing offshore renewable energy solutions (wave and tidal) for European ports. Irish Partners are MaREI-UCC and Shannon Foynes Port.
- **INTERREG Ireland-Wales Selkie** Project addresses identified gaps that are slowing the progression of the wave and tidal energy sectors. Irish Partners are MaREI-UCC, GDG ltd and DP Energy.
- **INTERREG Northern Ireland, Ireland and Scotland BRYDEN PHD Programme.** This programme offers fully funded PhD Studentships in Marine renewable energy and Bioenergy 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 2021. 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 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 devices and supporting technologies are demonstrated in real sea conditions, helping to leverage the investment needed to take these new products to market. Irish Partners in the project are Smartbay Ireland who are providing access to the SmartBay marine and renewable energy test site through the project funding mechanism. The FORESEA project was completed in December 2019.
- **INTERREG AA Blue-GIFT Project:** The €2.5M Blue-GIFT (Blue Growth and Innovation Fast Tracked) project kicked off and announced its 1st call for applications in April. Funded by Interreg Atlantic Area, the Blue-GIFT project is a coordinated ocean energy technology demonstration programme encouraging longer-term demonstration and technology de-risking across the Atlantic Area regions. The 1st call offers support package vouchers to ocean energy companies for access to demonstration sites across the Atlantic Area, lowering costs for testing and validating technologies in real sea environments. The project aims to support a minimum of eight floating wind, wave or tidal demonstration related projects across the Atlantic Area region. SmartBay Ireland's role in the project is to transfer know how gained from the very successful FORESEA project and to coordinate and administer the applications and call procedure in the project.
- **INTERREG NWE OceanDemo:** This is a follow-on project from the successful FORESEA project, which targets multi-machine ocean energy demonstrations. OceanDEMO recognises that the transition from single machine to pilot farm scale is critical for the future of the ocean energy sector. The project aims to ease the transition towards pilot farms by providing free access to Europe's network of open sea test centres: EMEC – European Marine Energy Centre, UK; DMEC– Dutch Marine Energy Centre, Netherlands; Centrale Nantes/SEM-REV – *Site d'Expérimentation en Mer pour la Récupération de l'Énergie des Vagues*, France; and the SmartBay Marine and Renewable Energy Test Site. The project released its first call for applications in May this year and devices will be installed from 2020 to 2022. In the first call, OceanDemo recommended one Irish company for support to trial and validate their wireless communications solution developed for the offshore wind sector. The 2nd call for applications is currently open.

Technology Demonstration

Projects in the Water

In 2017, DesignPro were funded €1.9M from EU's Horizon 2020 SME Instrument Programme for a €2.7M 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 SEENEOH test site in Bordeaux, France where it is undergoing rigorous performance and environmental testing.

There was also some testing activity in the Smartbay test site in Galway. In early February, the Centre for Renewable Energy at Dundalk IT (CREDIT) deployed their WASP (Wave power activated Sensor) buoy at the SmartBay test site. The research project was funded by the National Infrastructure Access Programme (NIAP) 2016 and the project aims to develop a low-cost, wave-powered sensor buoy to measure local sea wave conditions. The prototype buoy is in its first phase of a multi-phase prototype development process. The WASP uses a novel, pressure-based method for measuring sea-states, a technique which has been proven at wave tank model scale. The current, proof-of-concept, device makes use of state-of-the-art sensing, recording and communication equipment but another objective of the project is to develop a low-cost alternative to what is commercially available.

Planned Deployments

New Wave Technology, trading as Ocean Energy, plan to deploy a half scale model to test in US Navy WETS facility in Hawaii in Q1 2020. 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, build, transport and access to the site. The technology was transported from Oregon to Hawaii in November 2019 and in now awaiting access to the test site. It is anticipated that a year testing regime will follow.

This project 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 near complete construction at the Vigor yard in Portland, USA

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. In 2019, the event took place in Dublin, Ireland. The conference provided opportunities to network and obtain access to decision makers, thought leaders, investors and entrepreneurs in the sector. The event coincided with meetings of IEA-OES Executive Committee and IRENA, for the first time, which encouraged greater international collaboration and networking opportunities for key policy makers in the sector. The event was attended by over 400 people.

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.

Ocean Power Innovation Network

The Ocean Power Innovation Network (OPIN) ran a key event in Dublin in September 2019 to introduce the concept of the project to the market and to discuss key supports available in the project. The event presented on the key supports available in OPIN which are:

- Access to free masterclasses and workshops.
- Access to free Technical assessments.
- Access to supports for collaborative projects.

The OPIN network now has 170 members and is growing.

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

Italy

Renewables are expected to grow remarkably in Italy, achieving high levels of penetration in the electricity sector, around 55%. 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.

Supporting Policies for Ocean Energy

National Strategy

Renewables are expected to grow remarkably in Italy, achieving high levels of penetration in the electricity sector, around 55%. 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 announced that ad hoc measurements will be put in force for such innovative technologies, evaluating different supporting schemes.

The cluster “Blue Italian Growth” (BIG), led by the Italian National Research Council (Consiglio Nazionale delle Ricerche – CNR), has continued the 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.

Market Incentives

The Ministerial Decree 04/07/2019 is the latest issued support scheme, with the aim of promoting, through financial support, the diffusion of plants for the production of electricity from small, medium and large size renewable sources. In line with the D.M. 06/07/2012 and the D.M. 23/06/2016, registries and auctions are available to access incentives, which are dedicated to newly built photovoltaic plants, on shore wind turbines, hydroelectric plants and those with purification gas; according to NECP, support for innovative technologies will be provided through following ad-hoc schemes, which will evaluate several kinds of promotion, depending on the maturity level of technologies.

D.M. 23/06/2016 was the latest scheme providing support for ocean energy. The Decree identifies four different ways of access the 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.

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 for managing incentives for 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 60kW, 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[11]	Registry

From 2013 to 2016, the total annual capacity (MW) eligible for access to registries, and therefore for granting incentives, amounted to 6 MW. To this day, only one project, with capacity of 50 kW, located in Tuscany, participated to the registry. The plant was then realized and presented formal request to access incentives, but such request was rejected. The Decree does not provide for Dutch Auctions for wave and tidal energy power plants.

For new wave and tidal energy power plants, DM 23/6/2016 has 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.

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), purses 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 orienteering 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 were issued:

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

- 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. 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 for the rationalization of the Italian activities in the BE 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.

Research & Development

Research Infrastructures

Design and installation of the SeaPower Natural Laboratory in Villa 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 s.c.r.l., a non-profit private consortium that already patented new marine energy converters, is also 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 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 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.

Towing tanks

Small and medium scale prototypes are used in wave flumes and wave tanks where a specific sea state can be artificially created, and power production and device survival assessed. While scaling down the system, the wave tank/flume features are also to be considered, to scale the prototype according to the characteristics of the facility that is going to be used.

In particular, the CNR-INSEAN offers research infrastructures that include world-class towing tanks and flume tanks, thus providing a relevant testing environment for wave, tidal, offshore wind energy systems. The facilities provided are among the largest worldwide, and consist of:

- a 460 x 13.5 x 6.5 m calm water tank
- a 240 x 9 x 3.5 m wave tank
- a 12 x 3.6 x 2.3 m depressurised circulating water channel

These infrastructures are used to test large-scale models of concepts with TRL up to 5 and allow the simulation of real operating conditions at sea, accounting for the combined effects of winds, currents and waves. The facilities are equipped with advanced measuring systems in order to provide the complete characterization of device performance and response to simulated operating conditions, including extreme events. Testing activity is supported by in-house laboratories for the design, manufacturing and maintenance of test models and of the related equipment. A moving laboratory to support field site measurements is being developed to support on-site characterization and prototype operation activities. The CNR facilities have been included in the leading internationally distributed infrastructure MARINERG-I, designed to accelerate the research development and deployment of offshore renewable energy.

Innovative Converters

PIVOT Wave Converter

The PIVOT system is a wave energy converter that consists in a hinged floating body oscillating under the effect of wave motion and an electric generator, connected via hi-tech components. It has been developed from the GEL prototype by SeaPower s.c.r.l.in collaboration with the University of Naples "Federico II". 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. Both reduced-scale and full-scale prototypes of the system, have been tank tested, reaching TRL 5. The PIVOT concept can be exploited in different configurations, by using alternative PTOs or by adapting the mobile and fixed structures to specific requirements. A system based on an oscillating floating body is currently under development. The new configuration will be designed for both offshore and onshore installation, so as it will expand the range of its possible uses and will minimize the risk of disruption from extreme waves to which onshore plants are exposed.

The E-WAVE 100 converter for near-shore installation

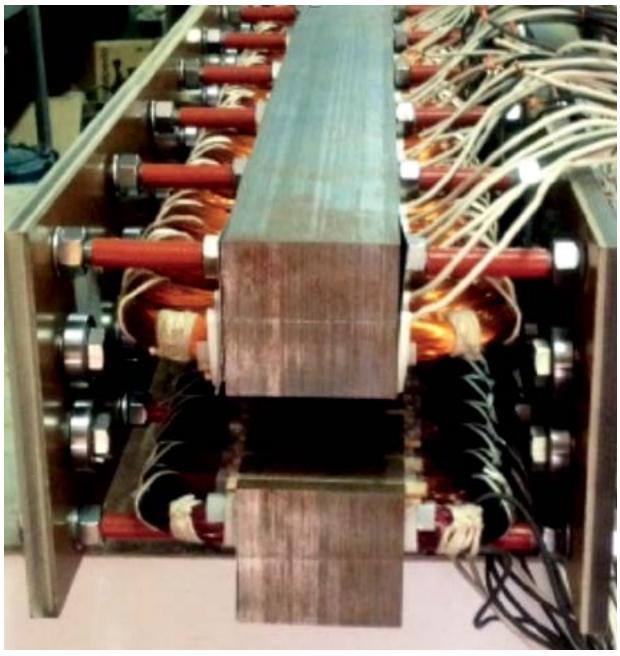
The E-WAVE 100 converter consists in a dual-chamber Oscillating Water Column (OWC) device, designed for being integrated into vertical-wall breakwaters. The two chambers that constitute the device act in charge/discharge mode respectively and are both equipped with specifically adapted non-return valves. 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 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. 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. Future activities include testing in real sea environment but low energy conditions, operative testing in areas suitable for pre-commercial installations and optimization of production technologies and materials to minimize the LCoE.

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 IMPETUS prototype

The ECOMar 100 wave energy converter 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. The project is based on a system which, by means of a float, captures the movement of the waves by feeding a hydraulic circuit which in turn operates an electric motor (cimoelectric system).It is modular and it can be upscaled from installation of a few KWh to very large plants. It can be installed adjacent to both existing and newly built maritime protection works (marinas and breakwaters). A 1:8 prototype has been tank tested in the AM3Spin-off laboratory of the University of Florence, while a pilot plant is under development. On 13 December 2019, the Apulia Region Economic Development Department and the company Kuma Energy signed a contract which provides for the construction of a pilot plant for the measurement of wave motion in the harbour of Taranto, preparatory to the construction of plants to produce energy from the sea.

The ECOMar 100 wave prototype

WAVESAX

RSE (Ricerca sul Sistema Energetico - Research on the Energy System) S.P.A. developed WAVESAX (TRL 5/6), an innovative wave converter within the OWC category, registered before the European Patent Office (Patent Document N. 2 848 802 B1, European Patent Bulletin 2016/23). This device has been conceived for its integration in coastal structures. It consists of a vertical pipe in which water moves upward and downward, following the wave motion. Inside the pipe a hydraulic turbine is positioned, that transforms the energy of the moving water into electricity. The turbine is of a bi-directional type (i.e. the rotor rotates in the same direction during both the ascending and the descending phase of water motion). Laboratory test studies have been performed on a scale model (1:20) in the ocean wave basin of the HMRC - Hydraulic Marine Research Centre (Cork, Ireland). A second 1:5 scale prototype, (see figure below), has been tested at the ECN Hydrodynamic and Ocean Engineering Tank (Nantes, France), in order to study different rotor configurations under regular and irregular wave conditions, while the facilities provided by CNR-INSEAN permitted the assessment of device performance for different turbine configurations and control strategies.

The WAVESAX 1:5 scale prototype

Technology Demonstration

In Italy there is an increasing interest in the exploitation of wave and tidal energy converters. In particular, wave energy converters integrated into conventional breakwaters have gained more and more interest among the port managers, as they offer the opportunity of energy self-sufficiency for the infrastructures in conjunction with a limited increase in costs and with ease of maintenance. Italian companies engaged in the supply chain for wave and tidal

energy converters detain long-term experience and innovation capacity, which can support all the specific steps of the design and production process. The most promising devices that have been developed and improved in the last years are reported below.

Recognition of the main projects in Italy by 2019

Project name	Project type	Project status	Name of water body	Capacity (kW)
REWEC3 @ Civitavecchia	wave energy	consent authorised	Tyrrhenian Sea Civitavecchia	2500
Overtopping Breakwater for Energy Conversion (OBREC)	wave energy	fully operational	Tyrrhenian Sea Napoli	1
ISWEC demonstration	wave energy	fully installed - missing grid connection	Mediterranean Sea	100
MaREnergy	wave energy	fully operational	Adriatic Sea Ravenna	3
Marina di Pisa H-WEP1	wave energy	fully operational	Tyrrhenian Sea Marina di Pisa	10
Kobold I	tidal current	fully operational	Mediterranean Sea	55
GEMSTAR Demonstration II	tidal current	early planning	Mediterranean Sea	300

REWEC3

The Mediterranea University of Reggio Calabria has been developing the REsonant Wave Energy Converter (REWEC3), which is a specific type of Oscillating Water Column (OWC) incorporated into a traditional vertical breakwater of monolithic reinforced concrete structure type. This activity is being carried out in cooperation with Wavenergy.it – an Academic Spin-Off of the Mediterranea University. It consists of a vertical pneumatic chamber connected to the open wave field by a U-duct. This device is composed of a chamber that contains a water column in its lower part and, an air pocket in its upper part. In addition, a REWEC3 also includes a small vertical U-shaped duct for connecting the water column to the open sea. A small-scale device has been installed at the Natural Laboratory of the University in 2005. The Rewec3 has already been installed in the port of Civitavecchia (Rome) and the famous architect Renzo Piano plans to insert it in the new port of Genoa. It will soon also be built in the Port of Salerno and Roccella Ionica (Reggio Calabria) and its installation will be evaluated both in the Principality of Monaco and in Belgium to protect the artificial islands. About the first full-scale prototype built in the port of Civitavecchia, the Port Authority of Civitavecchia decided to upgrade its infrastructure and adopted the REWEC3 technology for the realization of 17 new caisson breakwaters. Each REWEC3 caisson is 33.94 m long and includes 6-8 independent absorbing chambers. The total length of REWEC3 caissons is 578 m. A first Wells turbine of 20 kW, without any optimization, has been installed, while the total installed power will be 2.5 MW.

Overtopping Breakwater for Energy Conversion (OBREC)

The University of Campania Luigi Vanvitelli has developed OBREC, a device embedded into a breakwater and based on the wave overtopping process. A 1:30 scale prototype was tested at Aalborg University (Denmark) during two complementary experimental test campaigns in 2012 and 2014. Tests have shown that the integration of an OBREC into a breakwater improves its overall performances. A full-scale, 6 m long prototype has been installed in the port of Naples in 2015, along the San Vincenzo rubble mound breakwater, where sea depth is about 25 m. The overall performance of the device is being monitored.

Breakwater equipped with the OBREC prototype in the port of Naples

ISWEC Demonstration

The Polytechnic of Turin developed ISWEC (Inertial Sea Wave Energy Converter), a point-absorber wave converter suitable for mild climate seas such as the Mediterranean. It is based on the gyroscopic technology already used in marine applications for roll stabilization, except that the direction of energy transfer is reversed, with the gyroscopic torque induced by the incoming waves being exploited by the electrical PTO. The main characteristic of ISWEC is the possibility of controlling the flywheel spinning velocity to match the sea state and increase the productivity of the device. On August 2016, the first full-scale ISWEC prototype, with a nominal power of 100kW, was moored 800 m from the coast of Pantelleria. In March 2019, another ISWEC pilot project has been put into operation, with a nominal capacity of 50 kW. The plant is located in the Adriatic Sea off the coast of Ravenna and was created thanks to the partnership between Eni and the Polytechnic of Turin (PoliTO) and the spin-off Wave for Energy. The unit is part of a hybrid system that integrates photovoltaics and storage. The plant has reached a peak of power exceeding 51 kW, or 103% of its nominal capacity. Experimentation in the Ravenna offshore will not only assess the potential of marine energy exploitable but will offer the oil company a possible project for the conversion of mature offshore platforms into hubs for the generation of renewable electricity.

In October 2019, Fincantieri, Cassa depositi e Prestiti, ENI and Terna joined forces to produce energy from the waves. This agreement will launch the first phase of a joint project to convert ISWEC into an industrial scale power station. The partnership agreement will focus on two phases: during the first phase, the companies will develop a business model and define a deployment plan for Italy. At the same time, the first ISWEC industrial installation will be completed near to ENI's Prezioso platform in the Strait of Sicily, in the Gela offshore, with a launch planned for the second half of 2020. During the second phase, the parties will work on the formal constitution of the new company, in addition to devising a plan for the production and development of activities, starting with the implementation in Italy's minor islands first, and abroad at a later stage.

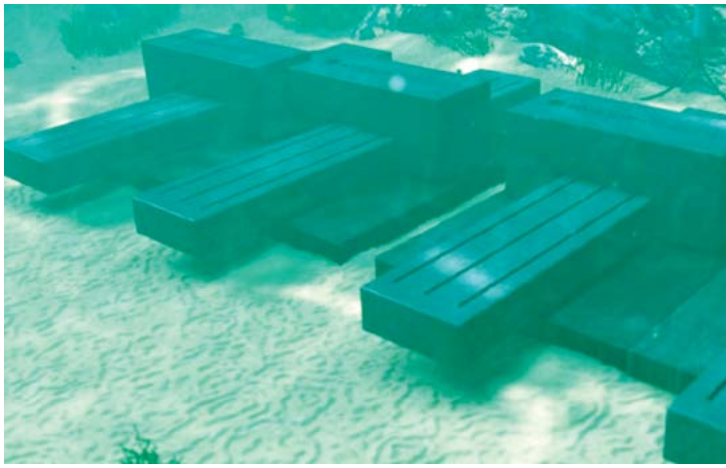
Marina di Pisa H-WEP1

H-WEP was first deployed off the coast of Marina di Pisa (Tuscany) by 40South Energy and since September 2018 is operated and managed by Enel Green Power. The H24 system has the shape of a large table about 2 m high and 20 m long.

KOBOLD turbine

The Aircaft Design & AeroflightDynamics Group (ADAG) of the University of Naples "Federico II", in cooperation with SeaPower Scrl, has long been designing systems for the extraction of energy from marine currents. It developed and patented the KOBOLD turbine which has been in operation since 2000. The nominal power output is 30 kW and the device is connected to the distribution grid.

ISWEC installation offshore Ravenna coast



H-WEP 1 layout on the seabed

The Kobold installation

Deployment of OPT PowerBuoy in the Adriatic Sea

GEMSTAR

ADAG and SeaPower s.c.r.l., in cooperation with Ing. Morrone, also designed GEM, the Ocean's Kite, an ocean current energy conversion system that consists of a submerged body with two horizontal axis hydro turbines. It is tethered to the seabed and free to self-orienting to the current. The device is placed at the desired depth thanks to its self-towing winch and is easily recovered to the surface for maintenance. A first full-scale prototype of 100 kW has been deployed in Venice lagoon. A full-scale prototype of 300 kW will be installed in the Strait of Messina. GEMSTAR is a submerged floating tidal current hydrokinetic turbine system (an evolution of GEM turbine). It is made by a submerged floating body supporting two hydrokinetic turbines, tethered to the seabed through a flexible cable and a single anchoring point, and able to align with tidal current direction changes. A new blade design approach has been introduced in order to comply with the requirements of a fixed pitch control strategy.

PowerBuoy

Ocean Power Technologies (OPT) PowerBuoy has been deployed in the Adriatic Sea since November 2018 by oil and gas company Eni in a project aiming to demonstrate suitability of wave energy technologies in oil and gas operations. Operating continuously and error-free for six months, as part of Eni's MaREnergy project, PB3 PowerBuoy has produced more than 1 MWh cumulative energy to date. The OPT PowerBuoy will be used to advance Eni's research and development of proprietary integrated subsea technology systems to allow future applications for remotely controlled field developments powered by wave energy, environmental monitoring and offshore asset inspection using autonomous underwater vehicles (AUVs). The demonstration will see OPT's device used for subsea battery charging, which eventually may lead to adoption of the device as a standalone charging station and communications platform that would enable the long-term remote operation of AUVs.

Relevant National Events

In September 2019, Naples hosted the European Wave and Tidal Energy Conference (EWTEC), the biennial international conference dedicated to renewable technologies from marine sources. To take stock of the state of the art of marine energy and to deepen the main development trends of the coming years, 600 of the world's leading experts in the sector met in Naples. Enel Green Power was the main sponsor of EWTEC.

Mexico

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.

Overview

A program 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 program, a theoretical assessment of wave, current, saline gradient and thermal gradient energy resources in Mexico has been elaborated by CEMIE-Oceano. Among the objectives of developing ocean energy in Mexico is extending off-grid access to electricity. Another concerns the challenges around clean energy materials (e.g. superhydrophobic, nanostructured ceramic and polymeric coatings). Progress has been made in the instrumentation of two natural laboratories, the updating of laboratory facilities, 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 wave 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 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. It is therefore estimated now 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-Oceano for 2009 was around 2 million euros.

Market Incentives

Mexico has introduced Clean Energy Certificates available to those companies which produce a certain amount of clean electricity or do not produce CO_2 emissions, as defined in Article 3, section XXII of the Electricity Industry Law, (ocean energy section). By 2019, it is obligatory for all 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 an 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 program 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:

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

Research & Development

CEMIE-Oceano

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; wave power availability in Mexican waters is being evaluated; a database is under construction, with in situ data and numerical model; Blow-Jet and 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 has begun “Physical Modelling in Large Infrastructure” in collaboration with institutions from Spain, Germany, Uruguay, Costa Rica and the Dominican Republic.

The **Tidal and Current Group** is carrying out: a) in situ measurements and numerical models assessment of tidal and ocean current energy, thus identifying two regions where harvesting this type of energy is feasible: the northern Gulf of California (tidal range of ~ 6 m), and the northern Mexican Caribbean (unidirectional currents > 1.0 m/s); b) development or adaption of technologies that are suited for the environmental and socio-economic conditions found in Mexico, and; c) evaluations of possible impacts to the environment that energy extraction from marine currents might generate, such as the alteration of current magnitude and direction on oceanographic processes (dynamic uplift), and on dispersion patterns (plankton, pollutants).

The **Salinity Gradient Group** has been collecting data from two representative coastal systems in México, a coastal lagoon and a river mouth, for a year. Field surveys were also carried out in other places to have a better understanding of the behaviour of salinity gradient in typical climate conditions elsewhere in Mexico. Currently, the group is working on building

both physical and biological databases, and a Mexican Atlas of this resource is under construction. The next step is the determination of the energy potential of these coastal environments, considering physical and biological factors.

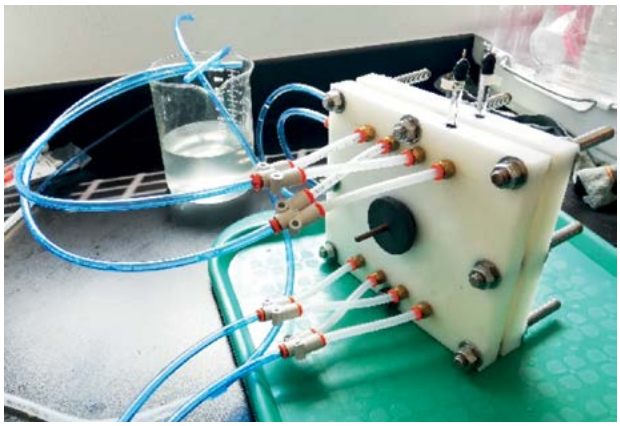
Regarding technology development, theoretical studies on the feasibility of Pressure Retarded Osmosis (PRO) and Reverse Electrodialysis (RED) are being conducted. Regarding the latter, three prototypes are being tested at laboratory scale to better understand various phenomena and to see possible adaptations to Mexican conditions. Also, under study is an ion exchange membrane, which might offer a trade-off between ion transfers and pressure drops, leading to a better performance of RED technology. Reducing biofouling is one of the main topics to address in order to scale-up RED technology for operations in natural waters.

The **Thermal Gradient Group** continues in the compilation of the atlas and is in the final phase of the construction of a prototype.

The Ecology Group has been working on: a diagnosis of potential ocean power generation zones, based on the geomorphological characteristics of the coast; the 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; an evaluation of the environmental consequences of harvesting this energy where sites have very important environmental assets, including fragile ecosystems such as coral reefs, and endangered species (vaquita and totoaba).

One of the biggest challenges in Ocean Energy development is the production of materials capable of withstanding both the harsh corrosion environment at sea and the growth of biomaterial on the surface of each component. Some equipment tested by the CEMIE-Oceano groups have shown considerable bio-incrustation after only 50 days at sea. CEMIE-Oceano is therefore developing non-toxic ceramic, polymeric and metallic coatings with no biocides. It is expected that in early 2020, these materials will be tested at sea, at 20 m depth, for a year.

Specific requirements for offshore generating marine stations have been established in some areas, where significant volumes of offshore energy have been developed, in terms of a) planning data and processes, b) technical performance and c) the regulatory regime. The compliance with the technical requirements of a grid code is measured at the point of connection to the transmission system. Depending upon the ownership and the grid configuration it is, however, possible that this connection point could be offshore, extending the power system to the offshore generator. As the radial transmission line is generally a sole-use asset, with no load or demand connected, the impact of



Investigation of salinity gradients

OTEC facility at CEMIE-Oceano

Equipment tested by the CEMIE-Oceano showing bio-incrustation after only 50 days at sea

non-compliance with certain Grid Code requirements is minimal. The benefit of compliance with certain requirements, e.g. reactive power control, is greatest closer to the existing system and demand, and the costs of installing mitigation offshore is correspondingly more expensive than onshore.

CEMIE-Oceano, increased activities in the dissemination of science, publishing 4 books: The impact of the Ocean in the Bioclimate of Mexico, Electrical Networks: Wholesale Electricity Market in Mexico, An Atlas of the Distribution and Abundance of Mammals In Mexico and An Atlas of the Impact of the Ocean on the Climate of Mexico. It also published two editions of the CEMIE-Oceano bulletin, which is its main form of dissemination, complemented by the website (www.cemieoceano.mx) and the publications on the social networks. In total, these media were consulted over 50% more often than in 2018.

WET-FLO (WElls Turbine FLoating OWC), consisting of an offshore floating OWC has been tested and characterized. This device uses a Wells turbine to capture both the upward and downward movements of the water within the column as well as that of air compression. The device was tested under irregular wave trains from where characteristic equations for the geometrical design as a function of local wave climate were obtained by means of a dimensional analysis.

Improvements on Reverse Electrodialysis cell composed of acrylic separators, excellion anionic membranes and titanium electrodes were achieved. The most efficient model had obstacles to the water flow over the membrane, increasing the Reynolds number and thus the power generation. The actual power output was similar, or greater than, that reported for cells with a similar membrane contact area, described in the available literature.

Laboratory installations for testing wave energy devices in Mexico have been improved with the construction of a wave tank, 9x15 m, 1.2 m deep, at the University of Campeche. The wave generator is a leading-edge snake composed of 15 articulated elements, allowing high precision, 3D wave generation.

A similar improvement in facilities has been provided through the construction of a wind tunnel on top of one of the existent wave flumes at the UNAM. Wind generated waves and wind perturbed wave trains can be produced. The wind direction is reversible, to go with or against the wave direction. These two facilities will be extensively used in the coming years to produce locally optimized technologies.

Wind tunnel at the UNAM

Technology Demonstration

Projects in the Water

CEMIE-Oceano continues to work in natural sites for testing wave energy devices in Ensenada, Baja California, and to test ocean current energy devices in the Cozumel Canal, Quintana Roo. Studies are being made and oceanographic measuring equipment has been acquired and deployed.

Planned Deployments

CEMIE-Oceano is planning installations soon:

- A wave energy device – Sauzal Port, Baja California
- An ocean current turbine – Cozumel Channel

Relevant National Events

An international workshop was organized by CEMIE-OCÉANO on Marine Microgrids and Energy Storage at the Universidad Autónoma de Zacatecas, Zacatecas, Mexico. 4-6 December 2019.

Several training courses for the formulation, administration and management of R,D&I projects took place.

Several training courses for the creation and management of technology-based companies also occurred.

Netherlands

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.

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, regarding 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 further techniques are developed 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 5m/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 were supported generously and erected quickly.

Market Incentives

For 2020, the generic national subsidy scheme (SDE, stimulating renewable energy), is being continued 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 abovementioned 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

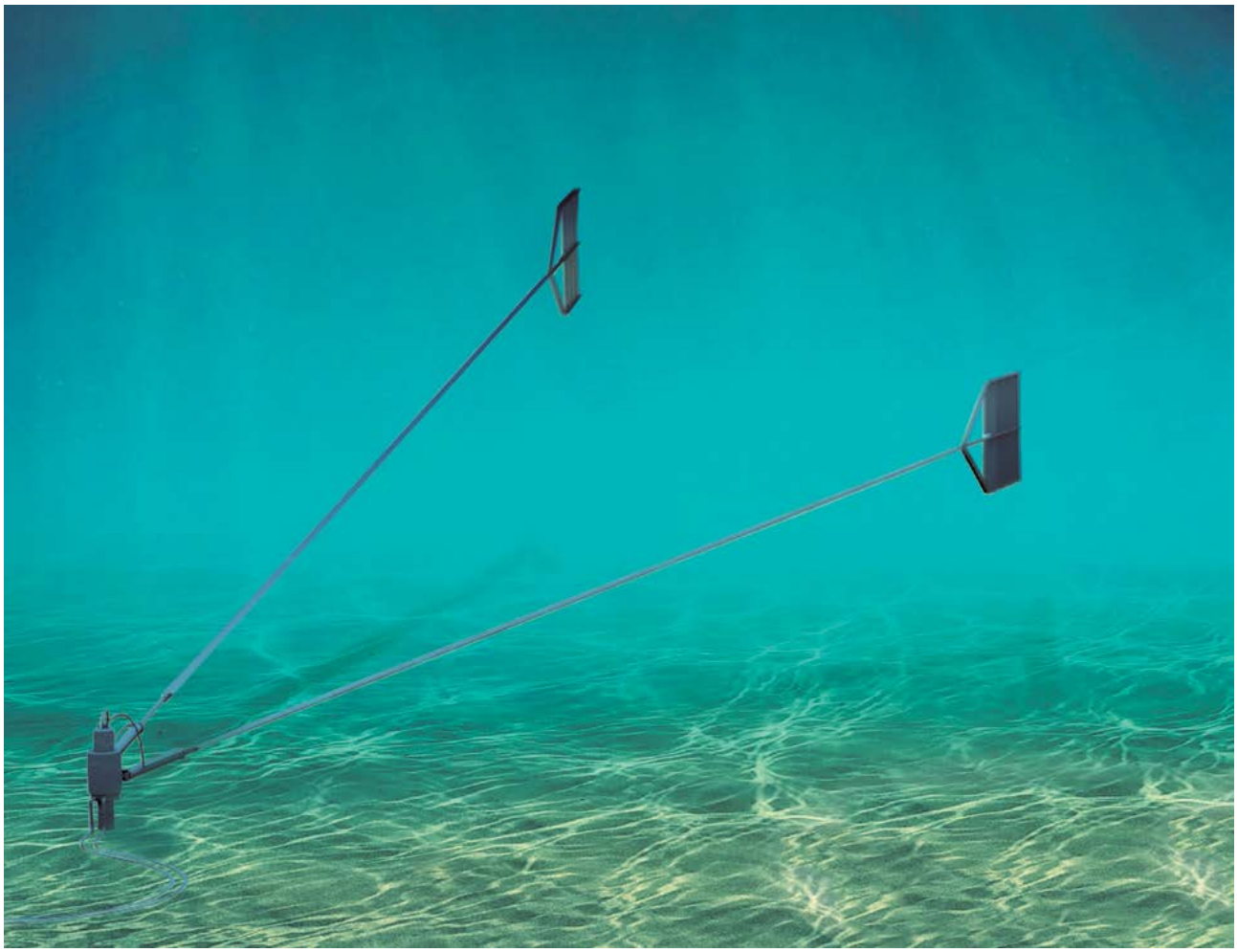
In 2019, SeaQurrent operated and tested a pilot on the Wadden Sea. Their tidal kite aims at moderate water speeds. In 2020, SeaQurrent plans a first commercial grid-connected demonstration project in the Wadden Sea, north of the Netherlands.

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 of 1 m3 river water with 1 m3 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 CO_2, is easily 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 in the pilot facility on the Afsluitdijk, Redstack now aims at a first demonstration plant at Katwijk (near The Hague), where the salinity gradient is optimal.

The opening of the Tidal Technology Centre Grevelingendam is further delayed with until 2020. This test facility offers three differently sized channels for low head tidal turbines.

On 9 October 2019, Tocardo was declared bankrupt. At the time of issue of this yearly update, there was no information about finding new partners or capital. In 2019, Tocardo further operated and tested their 1.25 MW tidal power plant in the Eastern Scheldt. Tocardo is still planning a 2 MW successor, also consisting of 5 separate turbines.



Salinity gradient pilot facility, Afsluitdijk

Tocardo Tidal Turbines

Technology Demonstration

Projects in the Water

Operational Projects

Tocardo, 1.25 MW tidal power plant in the Eastern Scheldt, operational since 2015.

Planned Deployments

- REDstack demoplant at Katwijk (near the Hague); planned in 2021
- Tidal Test Centrum Grevelingen Barrier; several techniques
- Follow up of Tocardo in Eastern Scheldt; 2 MW
- Brouwers Barrier tidal range plant (after 2020, various scenario's)
- Several arrays in Afsluitdijk discharge gates (further future)
- OTEC Pilot Curacao (500 kW), Bluerise was taken over bij Allseas, project is delayed.
- OTEC Pilot/Demo Martinique, Arteq power

Relevant National Events

On 7-9 October 2019, the Offshore Energy Exhibition & Conference (OEEC) was organized in cooperation with the Dutch Marine Energy Centre (DMEC) at Amsterdam RAI. This event is unique in bringing together the oil & gas, offshore wind and marine energy industry.

Norway

The joint green certificate market in Norway and Sweden is the market incentive used for ocean energy. Public R&D funding is available from The Research Council of Norway and Innovation Norway.

Overview

Offshore power production is to be regulated through the Ocean Energy Act. Consultancy on this has been held during 2019. Implementation of the act is expected in 2020.

The joint green certificate market in Norway and Sweden is the market incentive used for ocean energy. Public R&D funding is available from The Research Council of Norway and Innovation Norway. Public funding for demonstration is available from Enova.

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 during 2020. 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, nor overreaching support and incentive structures.

Market Incentives

Norway and Sweden have since 2012 been in a joint green certificate market. One certificate per MWh has since 2012 be given to all new renewable energy generation for 15 years, independent of technology. From year 2022 on, 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 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 program 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 program 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 3km/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. Same applies to the wave forecasting model installed, in co-operation with the Norwegian met. office.

Runde Environmental Centre (REC), located on Runde Island on the Norwegian west coast

Portugal

Portugal's Industrial Strategy for Ocean Renewable Energies (EI-ERO) was approved in 2017 and is based on two main goals: to stimulate export and value-added investment and to assist industry in reducing risks. An Action Plan (known as "Mar-Portugal") was prepared defining 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.

Supporting Policies for Ocean Energy

National Strategy

The Government of Portugal created, in 2015, the Ministry of the Sea, responsible for the coordination of maritime affairs, the promotion of a sustainable ocean economy, and the formation and monitoring of ocean policies based on scientific knowledge, innovation and technological development.

Portugal's Industrial Strategy for Ocean Renewable Energies (EI-ERO) was approved in 2017 and is based on two main goals: to stimulate export and value-added investment and to assist industry in reducing risks. An Action Plan (known as "Mar-Portugal") was prepared defining 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.

Mar-Portugal foresees "a set of measures focused on the development of a new R&D innovation model not only in wave energy, but also in offshore floating wind energy", with a view to create an industrial cluster exporting these new clean energy technologies. In this context, the implementation of the Windfloat Atlantic project offshore Viana do Castelo is considered of strategic importance for Portugal and a submarine cable has been installed by the national Transmission System Operator, connecting the 25MW floating offshore wind farm. This offshore site was also considered by the Government as the most appropriate location for the Portuguese sea test site for testing marine renewable energies (in particular, wind and wave energy)[12].

In 2019, the National Maritime Spatial Plan (PSOEM) was approved for mainland Portugal, Madeira, Azores and Extended Continental Shelf with a strategy for the compatibility of the different existing and potential activities in the sea, along with administrative online procedures for implementing projects in the ocean. PSOEM establishes the licensing regime for private use of the maritime space including marine renewable energies. A website has been created with all the information regarding Portuguese maritime spatial planning and also to support its public consultation (www.psoem.pt). An online platform has also been developed in order to submit the request for permits (www.bmar.pt). PSOEM thus creates a legal framework that facilites coherent, transparent, sustainable and informed decision-making processes in the Portuguese maritime space.

12 Resolução de Conselho de Ministros n.º 12/2018, de 19 de fevereiro

Public Funding Programmes

OCEANERA-NET COFUND

Fundação para a Ciência e a Tecnologia (FCT) is the national funding agency that supports science, technology and innovation, in all scientific domains. 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 which ended in 2018. Built on the work of this programme, the **OCEANERA-NET COFUND** has been launched running until 2021, supported by the EU's Horizon 2020 Programme. The participating countries/ regions are: Portugal, the Basque Country, Brittany, Ireland, Pays de la Loire, Scotland, Spain and Sweden. A call was launched on 8 January 2019 and closed on 5 April 2019, and Portugal (WavEC) is involved in one project, of the 9 projects selected for funding.

BLUE FUND & PORTUGAL VENTURES

The Sea Policy General Directorate (DGPM) has launched in 2017 the Call Fundo Azul ("Blue Fund"), an innovative public financial instrument, managed by the Ministry of the Sea, 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.

In 2019, Portugal Ventures launched the **Call Blue Economy** in partnership with Fundo Azul, allowing projects to obtain investment through venture capital, by Portugal Ventures and grants by Fundo Azul. This fund was set up with the purpose of supporting new business areas or new sectors of the sea economy, including ocean energy. The Call Blue Economy invests between €300 thousand and €1 million in innovative, science-based and technological projects that promote innovative solutions to stimulate the competitiveness of the main value chains and the development of the sea economy sector.

Research & Development

WavEC Offshore Renewables

WavEC is a private non-profit organization created in 2003 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.

In 2019, WavEC was involved in a number of projects related to wave energy technologies mainly funded by the European Commission (H2020, EASME and Interreg programmes) and one by Fundo Azul (national funding programme). These projects are listed below:

Projects running in 2019 at WavEC Offshore Renewables

Project	Funding Programme	Duration	Description
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 (Swedish 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 (Spanish technology).
DTOCEANPLUS	H2020	2018 – 2021	To develop advanced design tools for ocean energy technologies
ETIP OCEAN2	H2020	2019 – 2021	Strategy for the implementation of ocean energy at the European and global levels
LIFTWEC	H2020	2019 – 2021	Strategy for the implementation of ocean energy at the European and global levels
WESE	EASME	2018 – 2021	To develop environmental monitoring on wave energy converters operating at sea, in Southern Europe
BLUEGIFT	INTERREG	2019 – 2022	Support for testing marine renewable energy projects in test sites
BLUECAO	FUNDO AZUL	2018 – 2020	To develop an offshore platform to supply energy and feed offshore aquaculture based on oscillating water columns (OWC) wave energy converters (**coordinated by WavEC**)

Instituto Superior Técnico

Two groups were active on ocean energy at Instituto Superior Técnico (IST), University of Lisbon:

- 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 has been 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 OPERA project (H2020), in which, jointly with the Portuguese company Kymaner, they designed a prototype of the biradial self-rectifying air turbine with a new type of fixed guide vanes and a fast valve. The turbine-generator prototype was supplied by the Portuguese company Kymaner, and was installed on the MARMOK-A-5 spar-buoy OWC of the Spanish company Oceantec/IDOM, which operated successfully at the BiMEP test site (Bay of Biscay, Northern Spain) between October 2018 and May 2019. IDMEC/IST developed a wave-powered oceanographic buoy, based on the OWC spar-buoy concept, to be deployed in 2020 off the island of Faial, in the Azores Archipelago. IDMEC/

(a) Biradial air turbine after two years of sea trials in the Bay of Biscay, Northern Spain. (b) Wave-powered oceanographic buoy. (c) Model tests of wave-powered floating platform.

IST is also developing a general-purpose floating platform powered by OWC converters based on the new concept of co-axial ducts. Model testing was carried out in the large wave flume of National Civil Engineering Laboratory, Lisbon.

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) and moorings.

Faculty of Engineering of the University of Porto (FEUP)

In UPORTO, one group - Marine Energy Group - is actively involved in marine energy research and development with a particular focus on wave energy. This group was officially founded in 2014, with affiliated members from University of Porto and Interdisciplinary Centre of Marine and Environmental Research (CIIMAR). This group focus on R&D activities related to general sea energy harvesting and exploitation, including waves, current, tidal and offshore solar and wind energy. Following the works developed in the previous years, wave energy field was a major part of the research conducted in 2019. This group has contributed as a partner and/or leader to several scientific projects, focused on physical and numerical modelling of out-house and in-house innovative converters. The core research had key contributions on hydrodynamic optimisation, improvement of power take-off systems, comparative analysis of fixed and floating foundations applied to wave energy converters, among other topics. The team strategy has provided emphasis on the combination of numerical studies coupled with the large wave-basin and wave-current flume available at their laboratorial installations. In 5 years of existence, the Marine Energy Group has published more than 40 Scopus and ISI indexed scientific publications, on the topics of marine energy only. In 2019, the team was actively involved in 7 major R&D projects (5 focused on wave energy) and in the organisation of industry focused events, as the International Offshore Structures Design (IOSD) course or International Meetings, such as the 2nd General Assembly of WECANet - A Pan-European Network for Marine Renewable Energy with a Focus on Wave Energy 2019 [Porto, Portugal, 28-29 November, 2019].

In 2019, other projects as the PROTEUS or the ORACLE project, which focus on foundations' design adapted to Climate Change for offshore wind energy have also been main drivers of the team's multidisciplinary scope and the synergies created between wave energy research and other topics of great importance to the industry of renewable energy.

The project **PORTOS - Ports Towards Energy Self-Sufficiency** started in April 2019, coordinated by FEUP with a total budget of €2.6 million. The consortium is formed by 18 partners from all the 5 Atlantic Area countries (Portugal, Spain, France, United Kingdom and Ireland) with complementary expertise on the different marine renewable energy sources available at sea ports (waves, tidal, wind, solar, etc.) and implementing energy efficiency plans. It includes 3 Portuguese partners: FEUP, INEGI and the Port of Leixões. The objectives of PORTOS are, among others, to diagnose the energy demands and efficiency of target ports, and evaluate the potential and the needs for renewable energy supply and define strategies to adapt port infrastructures to the needs of the marine energy sector, supporting the development of novel technologies and promoting entrepreneurship and training on marine renewable energies.

Projects running in 2019 at the Marine Energy Group (FEUP)

Project	Funding Programme	Duration	Description
PORTOS - Ports Towards Energy Self-Sufficiency	Interreg | Atlantic Area	2019-2022	Aims to develop and promote the implementation of renewable energy, especially marine renewable energies such as wave, tidal and wind energy, at Atlantic Area ports.
WECANet	COST Action	2018-2022	Aims at understanding the main challenges governing the development of the wave energy sector, by providing a strong networking platform and creating the space for dialogue between all stakeholders in wave energy.
i.nano.WEC	DGPM - Fundo Azul	2018-2021	Aims to develop the first marine buoy prototype integrating highly efficient energy harvesting systems based on triboelectric nanogenerators.
SE@PORTS	OCEANERA-NET	2017-2019	Aims to assess existing WECs (TRL > 3) on their suitability to be integrated in breakwaters and develop a cost-efficient and flexible hybrid concept for harnessing wave energy in sea ports.
OPWEC - Optimisation of wave energy converters	FCT (under P2020|COMPETE and FEDER)	2016-2020	Study and optimization of two original wave energy conversion technologies using composite modelling.

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 during 2019 in the following tidal current energy project:

MONITOR – "Multi-model Investigation of Tidal Energy Converter Reliability": a 3-year 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:

- 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);
- to collect and process the resulting data; and
- 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.

In 2019, INEGI concluded the project SE@PORTS – "Sustainable Energy at Sea Ports", which involved the development of a hybrid wave energy converter based on the combination of an oscillating water column (OWC) and an overtopping device for application in harbours. This project was coordinated by INEGI with partners from Portugal and Spain.

INEGI has been further involved in two R&D projects with activities in the wave energy field:

- **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 started in 2019, coordinated by FEUP. The project aims to develop and promote the implementation of renewable energy, 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.

FÓRUM OCEANO

Fórum Oceano is a private non-profit corporate body, which aims to promote the Maritime Economy in Portugal, with more than 100 members in Portugal connected to many sectors of the Sea economy. On the ocean energy sector, Fórum Oceano has been mainly engaged in two projects, SE@PORTS led by INEGI and MATES (https://www.projectmates.eu/), funded by the Erasmus programme, running from 2018 to 2021 and aiming to develop a skills strategy that addresses the main drivers of change to the maritime industry, in particular shipbuilding and offshore renewable energy.

Technology Demonstration

Projects in the Water

AW-Energy

AW-Energy completed the final assembly and deployment of the First-Of-A-Kind 350 kW WaveRoller® in Peniche, Portugal during the autumn 2019. The unit was successfully connected to Portuguese national grid and started energy production in mid-November. AW-Energy Oy received Prototype Certification by Lloyd's Register (LR) for its WaveRoller device on 16 January 2020. This significant milestone is a prerequisite for commercial deliveries and follows the thorough process laid out in DNV-OSS-312 Certification of Tidal and Wave Energy Converters. It concludes several years of meticulous work and third-party scrutiny from scale-up and Technology Qualification to commercial scale device deployment. WaveRoller is a wave energy converter based on a hinged panel that is attached to the seabed. It is submerged in the near shore area and generates electricity from the back and forth movement of the waves (surge phenomenon). WaveRoller is connected to the electric grid via an onshore substation.

Deployment of the First-of-a-Kind (FOAK) WaveRoller (300 kW) offshore Peniche, Portugal

Planned Deployments

CorPower Ocean Portugal Lda

The Swedish wave energy developer CorPower Ocean has been planning the development of their first demonstration array at Aguçadoura test site, in northern Portugal, through the HiWave-5 project. Project partners include WavEC Offshore Renewables and EDP Innovation. Aguçadora, located in northern Portugal, is a test site with a cable connection to land and an onshore substation connecting to the national grid. Other marine renewable energy prototypes have previously been tested here, including the Windfloat technology. The project consists of the two final stages of a five-step product verification process and includes: Stage 4) Demonstration and prototype certification of single device full scale wave energy converter; Stage 5) Demonstration and type certification of pilot array with three wave energy converters. In 2019 CorPower initiated the permitting process and during 2020 the anchors, mooring systems and electrical infrastructure for phase 1 are planned to be installed.

Relevant National Events

IST has 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 2019. WavEC is also responsible for lecturing several modules of this course.

In 2019, WavEC organised its **Annual Seminar 2019** on the challenges and opportunities in the offshore renewable and aquaculture industry in collaboration with the Norwegian Embassy in Portugal. The event took place on 4 December 2019.

WavEC Annual Seminar 2019

Republic of Korea

Within the 2030 Ocean Energy Development Plan, the Ministry's action plan for developing and disseminating ocean energy systems, a strategic plan has been established in the field of tidal and wave energy development.

Overview

The Ministry of Oceans and Fisheries (MOF) has established a commercialization plan for ocean energy systems to contribute to the new national renewable energy policy of providing 20% of electricity from renewable sectors by 2030. Many R&D projects are being carried out to support this Ministry's commercialization plan. Korea Research Institute of Ships and Ocean Engineering (KRISO) is developing small wave energy converters (WECs) of the oscillating water column (OWC) type, combined with breakwaters and energy storage systems (ESS), to provide electricity to remote off-grid islands. A tidal current and pumped hydropower combined hybrid energy conversion system was tested at the Uldolmok test site in 2019. Additionally, two new R&D projects were initiated in 2019: (1) the development of a tidal energy converter combined with ESS to supply energy to remote off-grid islands, and (2) the development of a 1 MW class commercially available tidal energy converter. Korea Institute of Ocean Science and Technology (KIOST) is managing these projects within the tidal sector.

Two open-sea test sites for WECs and TECs are also being developed. The KRISO-Wave Energy Test Site (KRISO-WETS) will open in July 2020, and the Korea Tidal Current Energy Center (KTEC), established by KIOST, has been under development since May 2017 and is expected to be completed by December 2022. An ongoing international cooperation project (2018-2020) between South Korea and China will exchange technology development and the utilization of ocean energy systems. As part of this project, the second and third China-Korea Symposia on Marine Energy were held on Jeju Island and at Shandong University, respectively. The 7th International OTEC Symposium was held in Busan, South Korea, on 27-28 September 2019.

Supporting Policies for Ocean Energy

National Strategy

Within the 2030 Ocean Energy Development Plan, the Ministry's action plan for development and commercialization of ocean energy systems, a strategic plan has been established in the field of tidal and wave energy development. This plan is divided into four steps:

- the expansion of R&D in ocean energy and the establishment of open-sea test sites;
- the construction of large-scale ocean energy farms;
- the entrance into the global market and the expansion of domestic supply; and
- the establishment of an ocean energy certification system and supporting policies.

Market Incentives

The renewable portfolio standard (RPS) was established in 2012 to compel utility companies with a capacity greater than 500 MW to provide obligatory portions of their total electricity production from renewable energy, based on the Acts on the Development, Utilization, and Supply Promotion of Renewable Energy legislation. The market incentive plan, known as the tradable Renewable Energy Certificate (REC), supplements this 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, while the value of REC for wave and ocean thermal energy has not been determined. In the REC market, the REC price has gradually reduced from USD 140/REC in 2016 to USD 50/REC in 2019 due to the expansion of renewable energy supply as well as the stagnation of demand for REC by energy companies.

Public Funding Programmes

MOF provides public funding for ocean energy R&D projects, including demonstration projects. USD 16.2 million was invested in the development of ocean energy systems in 2019. The annual budget for ocean energy R&D projects is set to be USD 15.5 million in 2020.

Research & Development

As a part of a KRISO-led R&D project focusing on the development of wave energy converters applicable to breakwaters on remote islands, prototypes of energy conversion modules were manufactured as part of a wave power demonstration plant, in 2019. Also, a 30 kW permanent magnet generator and a ring-type impulse turbine were manufactured and tested. The experimental data evaluated in 2017 was selected as reference data in IEA-OES Task 10.4, i.e. a comparative study on numerical models for OWC-type WECs.

Performance test on prototype of impulse turbine with generator (Courtesy: KRISO)

Technology Demonstration

Projects in the Water

MOF is supporting two construction projects for open-sea test sites for WECs and TECs. The construction project for WECs started in May 2016 and will be finished in June 2020. The waters west of Jeju Island was selected as the test site. The existing Yongsoo OWC-type WEC is working as the first berth for the OWC-type WECs and as the offshore substation for the open-sea test site. It will also be used as a test bed for the digital twin technology development of the OWC-type WECs. KRISO has been in charge of developing the project, and the total budget is about USD 17.3 million. Four more berths, two in shallow water (20 meters) and two in deep water (40-60 meters), have been connected to the offshore substation and grid system, with a total capacity of 5 MW. The fifth berth, 60 meters deep, is also expected to be used for floating offshore wind turbines. The offshore cables were already installed in 2019.

The construction project for the open-sea test site for TECs (i.e., Korea Tidal Current Energy Center, KTEC), with five berths of 4.5 MW grid-connected capacity, has been underway by KIOST since May 2017 and will be finished in December 2022. Furthermore, the onshore performance test facilities for components of TECs, such as blades, will be also constructed at the KIOST Busan campus as a part of this project in the end of 2020. The southwestern waters of the Korean Peninsula have been considered as the tidal energy test site, as the Uldolmok tidal current pilot plant (TCPP) is operating nearby. The Uldolmok TCPP will be utilized as the test site for small- and medium-size TECs under 500 kW due to the limited water depth of about 25-30 meters. Several possible arrangements of test berths in the JangJook Strait were studied in 2018 and 2019, and an extensive consenting process was carried out, including environment impact and navigational safety assessments in 2019.

1 MW OTEC Plant

For the commercialization of ocean thermal energy converters (OTECs), KRISO is in charge of developing a 1 MW OTEC demonstration plant. A short-term demonstration was completed in the East Sea in September 2019, followed by its transfer and construction as an on-land type to conduct long-term operations in South Tarawa, Kiribati, in 2020-2021.

Relevant National Events

The 7th International OTEC Symposium was held in Busan, South Korea, on 27-28 September 2019, hosted by KRISO and the Korean Society of Power System Engineering (KSPSE). More than 100 individuals, from 10 countries, participated with the purpose of sharing the latest technology and information on research projects and industry activity. Following 25 oral presentations and 28 poster presentations, in two days, there was also a meeting of the International Energy Agency's Ocean Energy Systems (IEA-OES) task group on OTEC. Within of the symposium, participants attended a KRISO-led technical tour of the 1 MW gross-scale OTEC equipment, which had been installed on a barge in Busan Port, awaiting performance test in the southern region of the East Sea.

Singapore

In 2015, Singapore pledged to reduce its Emissions Intensity (EI, or GHG emissions per unit of GDP) by 36% 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 5.7 million as per data provided by the Department of Statistics Singapore in June 2019. 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% 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 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 comes mainly in the form of funding for Research & Development to develop capabilities within the industry. Singapore Power Group (SP) has been authorised as a local issuer of International Renewable Energy Certificates (I-RECs) or tradable certificates of energy from renewables in Singapore, the first in Asia Pacific. Each megawatt-hour of renewable energy produced is recorded as one REC and uniquely numbered and tracked. It will be used for achieving renewable energy targets and for reporting consumed energy as coming from renewable sources (SP Group, 2019). Enterprise Singapore has also formed a working committee TC114 on marine energy which is actively involved in adoption of international standards to support clean marine energy initiatives of the Singapore Government towards new industries such as aquaculture, desalination, electrification of marine operations, fisheries and tidal energy powered data centre systems, etc.

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 regions 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 the next five years (EDB, 2017). Over the past few years, Energy Market Authority of Singapore (EMA) has also awarded over $100 million to address industry-relevant challenges and opportunities in the energy sector that lead to long-term solutions for Singapore's energy challenges (EMA, 2019).

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

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 customized tidal turbines supported from the floating barges. Also, novel concepts such as floating solar system, anti-biofouling coatings are being evaluated for better field performance. The power developed is used for electric lighting on the boardwalk. This was further developed towards floating tidal turbine system.

ERI@N developed tidal turbine system.

Ocean Basin Facility – TCOMS

Technology Centre for Offshore and Marine Singapore (TCOMS) is a joint venture between the National University of Singapore (NUS) and the Agency for Science Technology and Research (A*STAR). A key feature of the TCOMS is the state-of-the-art Deepwater Ocean Basin, a massive water containment facility that can simulate the harsh environment of deep water oceans. The Deepwater Ocean Basin can hold a volume of water equal to over 20 Olympic-size swimming pools and has a 50m deep centre pit. Armed with smart sensing, modelling and data analytics capabilities, the next-generation Deepwater Ocean Basin can reproduce the wave and current systems of ultra-deep waters.

This enables researchers to study the complex ocean state and understand the deep-sea challenges facing the M&OE industry. Ultimately, this helps researchers to develop innovative solutions such as intelligent floating platforms, marine robotics and subsea systems to help the M&OE industry improve safety and enhance efficiency in the rough ocean waters.

TCOMS is currently working with its industry partners to solve real-world problems in the Marine & Offshore Engineering operations using state-of-the-art simulation techniques to better predict the behaviour and response of marine and offshore systems, such as rigs, smart vessels, tidal energy systems, floating structures and underwater systems.

TCOMS – Ocean Basin Facility

Projects in the Water

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 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.

As a next phase of the project, Mako Tidal Turbines in collaboration with Sentosa Development Corporation, Enterprise Singapore, Energy Research Institute @ NTU (ERI@N) and other industrial partners demonstrated a MAKO tidal turbine that is integrated with a Pylon of Sentosa Boardwalk in September 2019.

MAKO tidal turbine system demonstration in Sentosa waters

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,

Renewable Energy Integration Demonstrator Singapore

wind, tidal, energy storage, bioenergy, innovative water desalination, hydrogen production, etc. To date, the university has setup collaborations with around 30 local and international companies. Presently, the fish farm on the island is currently 100 % powered by clean energy harnessed from multiple renewable sources with an energy integration system.

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 completed in December 2017. During this project, the resource mapping methodologies have been well utilized to identify the ocean energy potential of the southern islands of Singapore identified by 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 deployment methodology for meeting energy needs towards the remote island region.

Deployment of Clean Energy Powered water generation system in 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 attracts large number of tourists every year. Presently, resource assessment for renewables in various southern islands is in progress.

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.
- Public Utilities board of Singapore has also issued a call for tenders for deploying a 50 megawatt-peak (MWp) floating solar PV system at Tengeh Reservoir by 2021.
- Two smaller floating solar PV systems will also be deployed by the PUB at the reservoirs in Bedok and Lower Seletar in the second half of this year.
- ERI@N is also currently working on small-scale deployment of 100 kWp seawater based floating solar systems.

Relevant National Events

4th and 5th Workshops on Tidal Current Extractable 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 a great variety 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. 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 5 March 2019 and 6 December 2019. There were attendees from various international tidal energy working teams from all over the world such as Dr. Jérôme Thiébot and his team from University of Caen, France; Dr. Sam Fredrickson and his team from University of Gothenburg, Sweden; Dr. Mathew Piggott and his team from Imperial College London, United Kingdom; Dr. Zhaoqing and his team from Pacific Northwest National Laboratory; Dr. Shuxiu Liang and the team from Dalian University of Technology, China; Dr. Prasad and his eam from National Institute of Ocean Technology (NIOT), India; Prof. Venugopal Vengatesan and his team from University of Edinburg, UK; Dr. Craig Stevens from National Institute of Water and Atmospheric Research, New Zealand and Dr. Narasimalu Srikanth and his team from Energy Research Institute @ NTU, Singapore.

Asian Conference on Energy, Power and Transportation Electrification (ACEPT) 2019

The Fourth Asian Conference on Energy, Power and Transportation Electrification (ACEPT) was organized by the 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 2019) in October 2019. ACEPT 2019 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 2019) in October 2019.

Floating Solar is taking the solar industry by storm! Globally, it unlocks 400,000 km2 of installation space on freshwater reservoirs alone, and thereby a new TW-scale opportunity for photovoltaics. It addresses the water-energy nexus through evaporation reduction and opens paths to ultra-low balance of system (BOS) costs. The fascination with scalability and market potential is palpable: New form factors have been discussed, and field tested and the young industry is charting its way through the options for electrical architectures and unfamiliar environmental considerations. Thus, various industry players, innovators, developers and other stakeholders of floating solar have been brought together.

International Floating Solar Symposium (IFSS).

Spain

2019 was a successful year for ocean energy in Spain. Several ongoing projects showed progress on reliability of ocean energy.

Overview

2019 was a successful 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), open sea operating experience gained with the end of the OPERA Project, several developments on corrosion and fouling resistant coatings were tested at the Marine Corrosion Test Site "El Bocal", the materials and components offshore laboratory – HarshLab – placed at BiMEP completed one year of operation. In addition, there was 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, some of them due to the technology development stage of ocean energy and some others due to the lack of a stable and proactive policy and legal framework to push forward the development of the sector.

Supporting Policies for Ocean Energy

National Strategy

During 2019, the Spanish Government continued working in the Energy and Climate National Integrated Plan 2021-2030, and in the Energy Transition and Climate Change Law. Both documents will fix the framework to develop new energy infrastructures, the energy source targets for 2030 and new rules to boost renewable energy in general and, hopefully, ocean energy specifically.

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 Energy and Climate National Integrated Plan 2021-2030, at draft stage, sets for ocean energy the target of reaching 25 MW of installed capacity for 2025 and 50 MW for 2030. The renewable energy contribution is expected to reach 42% in 2030.

Regarding the use of marine space, the Government is currently writing the maritime space management plans. A first draft of them has been written and during 2020 will go under public consultation.

Currently, there is not a specific organisation responsible for the implementation of any ocean energy programme, because up to now ocean energy has not been a priority in the Spanish policy.

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.

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 no specific for ocean energy. The only two programmes focused on ocean energy are:

- OCEANERA-NET COFUND (2017-2021) 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 Basque Energy Agency (EVE) launched a new call of its "Demonstration and validation of emerging marine renewable energy technologies" programme in 2019. 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, came to an end after 3.5 exciting years of research. 2019 saw the finalization of the second open-sea testing at BiMEP. The prototype included a high performance biradial turbine and advanced control laws previously tested at Mutriku. The shared mooring system configuration comprised two elastomeric tethers aimed at reducing peak loads, thus enhancing structural survivability. Comprehensive results analysis of the previous testing campaigns at Mutriku and at BiMEP has confirmed the potential of these innovations to significantly reduce the cost of wave energy generation.

More information at: http://opera-h2020.eu

During 2019, the third and fourth calls for trans-national access to European offshore renewable energy test facilities were assessed within the MARINET2 project, a H2020 programme project, which brought new users to HarshLab and Mutriku. 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.

BLUEGIFT - Blue Growth and Innovation Fast Tracked, is a €2.5 million European Regional Development Fund project that aims to help Atlantic Area companies test the next generation of Marine Renewable Energy (MRE) technology in real sea environments and prove power can be economically generated from the ocean. The project will result in a minimum of 8 MRE floating wind, wave or tidal pre-commercial demonstrations, over 24,000 hrs of operation, work with over 20 SME's, sustaining 30+ jobs and helping to secure €15 million investment into MRE companies. The BLUEGIFT consortium is integrated by test centres covering the major geographical spread and resource types and are evenly distributed across the Atlantic Area programme area: EMEC (wave and tidal) in Orkney, UK; SEENEOH (hydrokinetic and tidal) in Bordeaux, France; SmartBay (wave and floating wind) from Galway, Ireland; Centrale Nantes / SEM-REV (wave and floating wind) in Nantes, France; PLOCAN (wave and floating wind) on the Canary Islands; WavEC (wave and floating wind) in Portugal; and BiMEP (wave and floating wind) in Spain.

DTOceanPlus project, funded under the H2020 programme and coordinated by TECNALIA, is developing an integrated open-source suite of design tools to support the entire innovation and development process for ocean energy sub-systems, devices and arrays. Having reached its mid-term in October 2019, this three-year project has produced a set of functional and technical requirements to respond to user needs, and a novel framework to standardise data formats for Ocean Energy Systems.

More information at: https://www.dtoceanplus.eu/

NEMMO project (2019-2022), funded under the H2020 programme and coordinated by TECNALIA, will boost the competitiveness of tidal energy by optimising tidal turbine blade design and performance. The project aims to create a larger, lighter and more durable composite blade for floating tidal turbines, enabling devices to reach capacities of over 2 MW. Magallanes Renovables also participates in the project as key end-user partner and beneficiary of the prototype of blades to be manufactured in NEMMO.

SEA-TITAN project (2018-2021), funded under the H2020 programme and coordinated by WEDGE GLOBAL, continues making good progress. The project achieved a great number of milestones during 2019, completing the modelling and design of the new PTO modular unit

and prototype. Workshop and 4 publications have been released so far, with more to come in 2020.

More information at: http://seatitan.eu.

OCEANERA-NET Cofund project WEP+ concluded in 2019 with exceptional results, 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 5 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).

WESE is a project funded by the Executive Agency for Small and Medium-sized Enterprises (EAMSE) of the European Commission (http://www.wese-project.eu/). While the technological development of devices is growing fast, their potential environmental effects are not well known and interactions between devices and marine organisms or habitats that regulators or stakeholders are been perceived as a risk. The objective of the project is to collect and process environmental data from three wave energy devices installed at Spain and Portugal to improve the modeling capacity, develop a guide to obtain environmental permits, and to make the future location selection process easier for wave energy farms. This Interreg project has the participation of four Spanish partners (AZTI-Tecnalia, CTN, IDOM and BiMEP), two from Portugal (WavEC, HIDROMOD) and one from Finland (AW-Energy). During 2019 spring some campaigns were developed at BiMEP to collect environmental data prior the decommissioning of the OPERA project.

TRLplus, finished in 2019, was 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.

ELBE project is part of the European Union DG GROWTH "Cluster Go International" programme. ELBE aims to contribute positioning Europe as a world technological and industrial leader in Blue Energy, with a focus on emerging areas such as floating offshore wind, wave and tidal energy. The alliance gathers five European clusters in Scotland, Belgium, Sweden and Denmark, under the co-ordination of the Basque Energy Cluster, which together represent 455 Blue Energy organisations (including 28 testing and demonstration facilities, 20 wave energy developers, 5 tidal energy developers and 9 floating offshore wind platform developers). The purpose of ELBE during its first phase (2018-2019) was to forge a formal alliance between participating bodies and to define a joint internationalisation strategy. The deployment of this strategy will start in 2020, including direct missions to the USA (wave energy) and Canada (tidal energy), as well as an exploratory trip to Asia (wave energy) and several reports with the aim to give an updated view on key markets and to understand niche opportunities for ocean energy.

ELBE project aims to contribute positioning Europe as a world technological and industrial leader in Blue Energy, with a focus on emerging areas such as floating offshore wind, wave and tidal energy. The alliance gathers five European clusters in Scotland, Belgium, Sweden and Denmark, under the co-ordination of the Basque Energy Cluster, which together represent 455 Blue Energy organisations.

FLOTANT is a H2020 funded project led by PLOCAN as project coordinator. The main objective of FLOTANT project is to develop the conceptual and basic engineering, including performance tests of the mooring and anchoring systems and the dynamic cable to improve cost-efficiency, increased flexibility and robustness to a hybrid concrete-plastic floating structure implemented for DWWF.

Innovative solutions will be designed to be deployed in water depths from 100m to 600m, optimizing the LCOE of the floating solution (€85-95/MWh by 2030). Prototypes testing of this offshore wind floating platform and its associated mooring, anchoring and dynamic cable systems are foreseen in relevant environment and real sea conditions within the scope of the project. Moreover, the assessment and optimisation of the construction, installation and decommissioning techniques will also contribute to bring down the current cost of offshore wind energy, as well as increasing its deployment. An expected 60% reduction in CAPEX and 55% in the OPEX by 2030 will be directly motivated by FLOTANT novel developments and additional reductions due to external technology improvements. In addition, environmental, social and socio-economic impacts will be assessed, increasing social acceptance of FOW in deep waters. The tests which will be performed in the test site area of PLOCAN will follow the appropriate standards (ASTM D3623 and ASTM D6990) for testing and evaluating antifouling resistance of selected materials containing different percentages of additives in the marine environment. Test specimens without additives will serve as reference control. These activities are planned to start in July 2020, and they will continue along the project lifetime.

Technology Demonstration

Projects in the Water

BiMEP is an open sea test area located off the coast of Armintza, 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 hosted 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. The device was decommissioned in June 2019.

MARMOK-A-5 device after its decommission

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). Since its commissioning in September 2018, HarshLab has hosted almost 400 samples coming from 14 industrial companies, including materials from H2020 projects, such Marinet2 and NEMMO. TECNALIA is working on a bigger and more complex 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

Other test campaigns were carried out at BiMEP in 2019 by the company ZUNIBAL, its oceanographic buoy ANTEIA obtaining very good results to collect, in real time, height, direction and period data, as well as the water temperature.

Mutriku Wave Power Plant, the first multi-turbine wave energy facility in the world, has been integrated in BiMEP infrastructure, being now a second facility of BiMEP. The plant was connected to the grid in July 2011, reaching a record of cumulative energy from waves powered to the grid of close to 2 GWh, milestone that will be reached in January 2020. Two of the air chambers are prepared to test OWC components (air turbines, electrical generators, power converters and control systems). In the spring of 2019, the Irish company WAVERAM developed a test campaign taking advantage of MARINET2 funds.

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. In 2019, PLOCAN finished the Project REDSUB (2017-2019) awarded by the Smart Growth Operational Programme 2014-2020 co-funded by the European Regional Development Fund. The project consisted of conducting a series of activities that range from the design, acquisition and installation, to the commissioning of a sea-to-shore electricity grid and data network in the area. The electrical system installed is comprised of medium-voltage wiring and designed, fitted and sized to carry an initial maximum of up to 15 MW to shore to feed the electricity into the distribution grid (terrestrial electricity system). The deployment of the submarine electrical infrastructure (2 cables of 5 MW/13.2 kV) was finished during 2019, being currently one of the cables in operation. The installation of two submarine cables (5 MW/13,2 kV) started in 2017 and were commissioned during 2018. They are expected to be grid connected in 2019.

LifeDemoWave was a wave project developed in Galicia. Funded by the European Commission (LIFE+), the main objective of LifeDemoWave project was 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 25 kW wave energy prototype was developed and installed in the Galician coast in August 2018 for a no grid-connected test, and it was removed in April 2019. Six Spanish entities take part on this project: Quantum Innovative, Universidad de Vigo, CETMAR, Hercules Control, ACSM, and Grupo JOSMAR.

Galicia-based company **Magallanes Renovables** with its 1.7 MW power platform has been installed since February 2019 in Fall of Warness, in Orkney. Since last August 1, continuous and autonomous energy is being produced, pouring into the UK network. During the year 2019, Magallanes Renovables was able to validate the operability in real conditions and the performance obtained, demonstrating that the model is ready to begin its commercialization. During the year 2020, Magallanes Renovables intends to continue validating the generation and maintenance model and start commercialization in projects such as Morlais and in the EMEC. Magallanes Renovables has different European projects such as the NEMMO project where new blades will be developed to optimize the generated energy.

Planned Deployments

During 2020, several projects are expected to reach the waters in PLOCAN: The company **WAVEPISTON** is leading a project aiming to test a wave energy converter. The Wavepiston technology is developed on the shoulders of the first-generation wave energy technologies being protected by several patents. The prototype test and Phase 1 feasibility study have confirmed its potential. The Wavepiston system is easy to assemble on site by local staff and can be deployed from a regular tugboat, just like operations and maintenance can be carried out without expensive specialists. In the Phase 2, it will be installed a full-scale Wavepiston demonstration system to demonstrate the energy potential, durability and survivability ensuring a low cost per kWh in the PLOCAN test site during 2020.

In 2018, the Norwegian company **Tveter Power** started trials of a pumping device driven by wave power on the PLOCAN test site and will continue during 2020. The trials are used to take measurements of the pumping capacity of the prototype depending on the height of the predominant wave and the survival capacity of the device will be verified at sea. One of the potential applications of the kind of device on trial would be to provide sea water for coastal desalination plants without having to use electricity to pump the sea water. The first stage of the project was implemented in 2016 and 2017 on the Atlantic coast of Norway, where a preliminary version of the device underwent several resistance trials.

Relevant National Events

- EVE, TECNALIA and BEC (Bilbao Exhibition Centre) organised the fourth edition of Marine Energy Week as part of a wider maritime event “World Maritime Week”, in collaboration with the Basque Energy Cluster in February 2019.
- The Joint Research Laboratory on Offshore Renewable Energy (JRL-ORE, http://jrl-ore.com/) organised the sixth edition of the Euskampus Marine Energy Conference in Bilbao in June 2019.
- The Naval and Oceanic Engineer Spanish Association organized in June 2019 the 10th edition of ENERMAR (ENERMAR 2019) at Ferrol (Galicia).

Sweden

Key achievements in 2019 include progress for different Swedish developers in developing and demonstrating their technologies.

Overview

Key achievements in 2019 include progress for different Swedish developers in developing and demonstrating their technologies. CorPower won the EIT Venture Award against strong competition. There have also been activities at the test sites in Sweden, particularly at Kristineberg where a new research and innovation environment for sustainable blue growth is taking form. Finally, Swedish Energy Agency arranged an ocean energy conference with a focus on knowledge exchange and value chain development.

Supporting Policies for Ocean Energy

National Strategy

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 strategy[13] 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.

In December 2019 Swedish Agency for Marine and Water Management submitted the Swedish marine spatial plan proposals to the Swedish government. The government shall adopt plans by March 2021 the latest. Marine spatial planning will form part of the basis for agency and municipality decisions regarding the most appropriate usage of a marine area, considering the character and location of the area and the needs that exist. Ocean energy is mentioned in the plans, mainly as the need of test sites.

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. These instruments all provide incentives for renewable energy and does not specifically target a particular renewable electricity conversion

13 A summary in English can be found here: http://www.government.se/contentassets/9e9c9007f0944165855630ab4f59de01/a-swedish-maritime-strategy--for-people-jobs-and-the-environment
14 http://www.energimyndigheten.se/nyhetsarkiv/2017/energimyndigheten-antar-strategi-for-havsenergi/

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.

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 website[14]. The programme will run from 2018-2024 and has a total budget of around 10,2 Meuro. In the first call six projects were funded. A second call is being held at the moment. 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 Cofound, 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 and five projects were chosen, whereas two have Swedish stakeholders.

Research & Development

Swedish companies, universities and institutes have been involved with several research and development projects during 2019. Below are just a few examples.

Installation and maintenance methods of marine energy converters

The goal of the project is to investigate how different installation and maintenance (I&M) strategies impact the cost of generated electricity from marine sources, using as a metric the Levelized Cost of Energy (LCoE). Mapping of I&M strategies for marine energy converters with a focus on national developers will be carried out, identifying the needs and possible solutions for them. The study will help to reduce I&M time and costs, thus, to maximize the efficiency of the operations and, as a result, to lower the LCoE. The project is carried out by Uppsala University, SSPA, Ocean Harvesting Technologies (OHT) and Novige.

NextWave

By controlling the motion of the wave energy converter (WEC), the power production can be significantly increased. However, advanced control strategies require future information on individual incoming waves to be efficient and are thus not used in practical applications. This pre-study aims to investigate the use of affordable and efficient radar technology (as used in the automotive industry) to provide future wave information. By combining (i) wave radar, (ii) motion measurement of the WEC, and (iii) a machine learning algorithm, the forces acting on the WEC can be forecasted in real-time thus facilitating the use of control strategies. The project members incorporate the entire value chain: a radar supplier (Rosemount), a radar software specialist (SafeRadar), RISE and two wave energy technology developers (Ocean Harvesting Technologies and CorPower).

ELASTMOOR - Elastic mooring systems for wave energy converters (OCEANERA-Net project)

The project aims to improve the knowledge of using elastic mooring lines for wave energy applications. It will be achieved by collecting data from (i) laboratory testing of rubber, polyester and nylon lines, and of the coupled system of mooring and floater in an ocean basin test, and (ii) full-scale field tests of Waves4Power's wave energy converter. The results from the laboratory tests will be used for (iii) full-scale field tests of a

mooring made of rubber, polyester and nylon lines to be conducted in Portugal, and (iv) the development of constitutive models which will be implemented in an in-house mooring dynamics numerical model. The project is carried out by Chalmers University of Technology, University of Lisbon, Seaflex Energy Systems and Waves4Power.

WaveBoost (Horizon 2020 project)

The WaveBoost project was ended during 2019. The Waveboost project designed and developed an advanced PTO system which will allow wave technology to operate safely and reliably in harsh ocean conditions while increasing the Annual Electricity Production.

The WaveBoost project has brought together a consortium of sector leaders from Sweden, Portugal and the UK. The key project outcomes can be summarised as:

- Design of the advanced PTO, including an advanced braking system for greater control of movement and a 98% reduction on overall flow losses.
- Development of HIL-rig and test plans for the advanced PTO.
- FMECA and VMEA analysis of advanced PTO informing design and testing processes.
- Detailed modelling of advanced PTO within multiple wave energy applications.
- Accelerated testing of seals within a bespoke, state-of-the art Seal Test Rig, resulting in a 70% improvement on seal friction.
- Biofouling and corrosion testing in a real sea environment.
- Estimated 21.3% to 26.9% improvement in AEP, based on a target power matrix still undergoing validation.
- LCOE analysis undertaken of three array sizes; 50 MW, 300 MW and 1 GW. Estimated 18.0% to 29.3% reduction in LCOE.
- Socioeconomic analysis undertaken of a 50 MW array deployed in Scotland, resulting in €166M GVA and 2088 job years supported.

Combined Wind/Wave Ocean Deployments

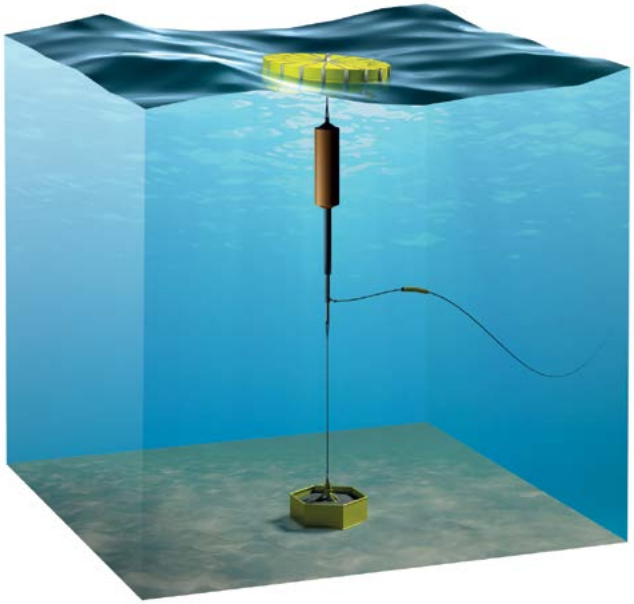
CorPower is working with several utility and energy companies to assess the feasibility of WEC installations in other locations. Some of these projects are looking at combined wave and wind arrays to take advantage of the natural time shift between the wave and wind resource. Such combined arrays may reduce output variability and increase revenue potential by enabling the supply of electricity at times with high market demand and low supply from wind turbines, a business case with increasing importance in markets with high penetration of wind power.

IWEC – Cost optimization for the InfinityWEC Wave Energy Converter

Ocean Harvesting Technologies has been developing the novel 500 kW InfinityWEC wave energy converter since 2017, building on the know-how of the wave power application and simulation capabilities developed since the start in 2007.

An LCoE based optimization project was started in April 2019. The project includes 1) CFD validation of simulation models, 2) Update of InfinityWEC system design, 3) extension of system design to a complete 100 MW wave farm installation with 200 WEC units, and 4) LCoE modelling and optimization where cost and performance are analyzed on component level with computer simulations for a range of system parameters, to find the optimal system configuration. The main objective is to show an LCoE of €100/MWh at 10 MW deployed capacity.

The project is carried out by OHT, Sigma Energy & Marine (SE), NSK and Teraloop.



InfinityWEC wave energy converter

Demonstration Projects

Open Sea Test Sites

Kristineberg Research and Innovation Center

The University of Gothenburg, Chalmers, KTH, IVL Swedish Environmental Institute, RISE and Lysekil Municipality are now jointly building a new research and innovation environment for sustainable blue growth. With close links to the West Swedish maritime cluster, the center will strengthen the opportunities to implement the national maritime strategy and achieve sustainability objective 14 on sea and marine resources.

The center is physically located at the renowned marine research station Kristineberg, west of Fiskebäckskil, which is currently run by the University of Gothenburg. Through the new collaboration, the station opens to new entrants and offers advanced marine infrastructure, test beds and demonstration environments. Kristineberg as a meeting place shall:

- Initiate, drive and coordinate research and innovation projects.
- Support entrepreneurship and business development.
- Be a meeting place for activities for collaboration and skills development.
- Offer test beds and advanced marine infrastructure.

An important part of the business is to support entrepreneurship and business development through, for example, innovation support and test beds for marine technology, especially marine energy. A project in the area is called the Test site Skagerrak and is aimed at stakeholders in mainly marine energy, offshore wind power as well as marine biomass and biotechnology. The test bed provides the opportunity for demonstration and development of marine techniques. Kristineberg forms the hub of the venture with its infrastructure in the form of vessels and technical personnel. Access to deep harbor, underwater robots and research divers for work and inspection in combination with proximity to qualified research makes the test environment unique.

Investments have been made under 2019 to provide better test support for testing in waves, in currents, with respect to antifouling, corrosion and effects on the marine environment. Examples of analysis that can be made is surface properties, failure analysis and adhesion.

Lysekil research test site

A force measurement buoy of 1m diameter were deployed at the Lysekil test site in May 2019. The buoy was installed for one month and collected data for 14 days. Data are currently analyzed and will be published in 2020.

Projects in the Water

Minesto develops a technology, called Deep Green, that can produce electricity from low-velocity tidal and ocean currents. In 2019 Minesto continued its first-of-its-kind demonstration project off North Wales at the company's Holyhead Deep site, where a 500 kW turbine was installed and initially commissioned in 2018. Through validation of installation procedures and commissioning of this 500 kW system, the company has taken a major step forward in demonstrating the functionality and capacity of the technology at Utility Scale. The 2019 test programme in particular encompassed offshore testing with an upgraded system with further key verification performed, including a new mooring and installation method which enables a greater variety of installation depth and thus an expanded geographical area of application.

Novige develops a point absorber that via a basic hydraulic cylinder pumps high pressure water up to a Pelton turbine that runs a generator. The concept is non-resonant. In December 2019 the small-scale unit (1 kW) was deployed at a site outside Stockholm.The unit has been tested for more than three weeks, also in harsh weather as well as in below zero temperatures and snow/ice. When the test period is finished in mid-January 2020, the unit will be prepared for wave tank testing in Plymouth.

NoviOcean tested outside Stockholm

Planned Deployments

CorPower Ocean develops a compact high-efficiency Wave Energy Converters, inspired by the pumping principles of the human heart. CorPower Stage 4-5 HiWave demonstration started in mid-2018 and continues to 2023. It consists of:

- Stage 4 – Demonstration and prototype certification of single device full scale C4 WEC, planned for 2018-2021. Taking the technology from TRL 7 to TRL 8.
- Stage 5 – Demonstration and type certification of pilot array with three C5 WECs, planned for 2021-2023. Taking the technology from TRL 8 to TRL 9.

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.

In 2019 and the first half of the 2020 CorPower is preparing for the ocean demonstration and prototype certification of its first full scale Wave Energy Converter (WEC), 300 kW power. Aguçadoura site in northern Portugal is chosen as the demonstration cite, which already has an onshore substation and a land cable in place. The anchors, the mooring system, the hull and the collection hub will be installed already during the summer 2020, followed by testing of the installed equipment in the autumn 2020. The full prototype will be deployed early 2021 and the ocean testing will take place until the third quarter of 2022.

The next step will be deployment and operational ocean demonstration of an array of three WECs, 300 kW each, in summer-spring of 2023.

A strategic collaboration agreement has been signed with a project developer, Simply Blue Energy (SBE), to deploy significant early commercial wave and wind farms across the coast of the UK and Ireland.

CorPower won the EIT Venture Award in 2019 against strong competition (€50M prize).

In 2020, **Minesto** will install two 100 kW turbines as part of a pilot project in the Faroe Islands. Minesto collaborates with the local electric utility company SEV to explore the potential of adding tidal stream generation capacity to the Faroese electricity mix. The two 100 kW Minesto systems will be installed in the Vestmannasund strait and will be connected to the main power grid. By utilising tidal stream energy, SEV assess that substantial investments in overcapacity in wind power and pumped storage capacity can be avoided, thus creating a balanced and cost-effective 100% renewable electric energy mix.

Waves4Power is a developer of a buoy based wave energy converter system. Waves4Power was approved by Interreg North-West Europe for the free Ocean Demo at EMEC. There are also plans to launch an upgraded demonstration unit at Runde and connect it to the power grid using existing infrastructure.

Relevant National Events

Havsenergiforum

In October 2019 the Swedish Energy Agency arranged the ocean energy conference Havsenergiforum. The theme was knowledge exchange and value chain development. During the day different project presentations took place,and ended with a panel debate with representatives from developing companies, academia, suppliers, test center and Ocean Energy Europe.

ELBE conference

In a highly anticipated event in Gothenburg, Sweden, international offshore clusters (AREG, Cluster de Energia, Energy Innovation Cluster, Blue Cluster and OffshoreVäst) met on 21 May to discuss potential European supply chains and projects within the blue energy sector.

The consortia is now planning for the next phase which will welcome additional European clusters to join the collaboration.

OffshoreVäst Annual Conference 23-24 January 2020, Gothenburg

The theme for this conference is “From Innovations to International Business” and the conference will lay the foundation for new research projects, collaborations and set the future course together for OffshoreVäst.

United Kingdom

With numerous projects in the water and thousands of MWh of electricity generation (including the world's largest tidal array MeyGen), 2019 was a growth year for the marine energy sector in the UK.

Overview

With numerous projects in the water and thousands of MWh of electricity generation (including the world's largest tidal array MeyGen), 2019 was a growth year for the marine energy sector in the UK. The year saw numerous innovative cross-border collaborations, deployment of state-of-the-art projects and offshore tests being undertaken. The UK is home to the first tidal stream arrays in the world and has already deployed more wave and tidal energy devices than the rest of the world. Even though most of these activities have been supported through Research and Development (R&D), a dedicated policy and revenue support for ocean energy is still required to deliver significant sustainable economic benefits. While the UK stands as a global leader in developing offshore renewable energy technologies, a reduction in technology costs is required for the sector to compete with alternative low-carbon technologies and contribute towards achieving the UK's net-zero target.

Wave

In 2019, the wave energy sector continued to engage in innovative R&D to drive the sector towards design convergence and commercialisation. 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. In 2019, the programme awarded £9m to eleven wave energy technology projects through various innovation projects and research activities. The Welsh European Funding Office (WEFO) in Wales also continues to contribute significantly to wave R&D with £30.4M being allocated for wave energy development since 2014.

Tidal Stream

In 2019, many tidal stream projects made significant progress towards commercialisation. By the end of 2019, SIMEC Atlantis' four-turbine 6 MW MeyGen project had clocked up over 23 GWh of generation with maintainability also demonstrated through recovery and reinstallation operations. The Nova Innovation three-turbine 0.3 MW array continued to operate, with the turbines accumulating over 20,000 hours generating power to the grid (as of Dec 2019). With the integration of a Tesla battery system, the turbines are now able to provide continuous power to the local grid. The Scottish tidal developer has also been granted licence to deploy a 1.5 MW tidal array starting 2020 in the Bay of Fundy area of Nova Scotia, Canada. The 2 MW floating SR2000 device from Orbital Marine Power also achieved 3GWh of generation over a year of continuous deployment. In 2019, Orbital Marine Power commenced construction of their optimised production model, the 2 MW Orbital O2, for deployment at The European Marine Energy Centre (EMEC) in 2020. Also in 2019, Minesto deployed their commercial scale low flow technology off the coast of Anglesey and have secured their first international orders for the Deep Green technology. The Tidal Stream Industry Energiser (TIGER) project was initiated in July 2019 planning to deploy up to 8 MW of new tidal capacity around the Channel region. In October 2019, the Tidal Stream sub-theme report was also published as a part of the Business, Energy and Industrial Strategy (BEIS) commissioned Energy Innovation Needs Assessment (EINA) that described the potential of tidal stream in the UK's energy mix.

Supporting Policies for Ocean Energy

National Strategy

The UK Government's Department for BEIS retains overall responsibility for energy policy in the UK while powers related to planning, fisheries and the promotion of energy efficiency are devolved to the governments of Scotland, Wales and Northern Ireland.

In May 2019, the Committee on Climate Change (CCC), the UK's independent climate advisory body published "Net Zero – The UK's contribution to stopping global warming". The report reassessed the UK's long-term emissions targets and recommended new greenhouse gas reductions targets for the UK, Scotland and Wales: 100% by 2050; 100% by 2045; and 95% by 2050 respectively. Following the recommendations, the net zero target for 2050 was passed into the UK legislation in June 2019, making the UK the first major economy to set a target to end its contribution to global greenhouse emission by 2050.

The Clean Growth Strategy (CGS) published in October 2017 by the UK Government had set out comprehensive policies and proposals to accelerate economic growth and decrease emissions. It stated that ocean energy technologies "could also have a role in the long term decarbonisation of the UK, but will need to demonstrate how they can compete with other forms of generation." The CGS was followed by the Industrial Strategy (IS), which includes sector deals, more recently updated for ten sectors (including offshore wind) and four Grand Challenges. The IS aims to push the UK to the industrial forefront, maximising potential advantages from the global low-carbon energy transition. Progress updates for the CGS along with the inclusion of new sectors into the IS were published in October 2018 and June 2019, respectively; however no references were made to ocean energy.

To further inform budget setting for 2019 onwards, BEIS commissioned the EINA that brought together UK Government funding agencies from across the UK to prioritise and allocate R&D investment to low-carbon technologies, including ocean energy. In October 2019, the EINA report on Tidal Stream that summarized innovation needs, market barriers and business opportunities for the tidal sector was published. However, post elections, a clear policy for 2020 has yet to be set as it will be included in the next comprehensive spending review.

SCOTLAND

The Scottish Energy Strategy sets out the Scottish Government's vision for the future of the energy sector to 2050. The Strategy is defined by a whole-system approach and includes a target to meet the equivalent of 50% of Scotland's heat, transport and electricity consumption from renewable sources by 2030. Following updated technical advice from the UK Committee on Climate Change (CCC), the Scottish Government amended its Climate Change Bill to a net-zero greenhouse gas emissions target by 2045. This is reflected in the first Annual Energy Statement published in 2019 that states the progress alongside the priorities and sets targets for the Scottish Energy Strategy.

The Scottish Government continues to champion the ocean energy sector, supporting the research, development, innovation and demonstration intended to maintain Scotland's position as a world leader in both wave and tidal energy. This includes providing ongoing support for Wave Energy Scotland (WES) and, in February 2019, establishing the Saltire Tidal Energy Challenge Fund (with a total funding of £10m) to accelerate the commercial deployment of tidal energy in Scottish waters. To date, the Scottish Government has invested nearly £40m in more than 90 projects through the WES programme. Through various innovation projects and research activities, funding of £9m was awarded in 2019, including £7.7m for two Scottish wave energy devices to be deployed in 2020. The Scottish Government also continues to support the Scottish Marine Energy Industry Working Group, to secure future growth and further industry cost reduction.

Marine Scotland, the Directorate of the Scottish Government responsible for the management of Scottish seas, including planning and licencing of marine energy projects, opened a consultation in November 2019 to seek views on a draft Offshore Renewables Decommissioning Guidance document. The consultation will close in March 2020 ahead of the final publication of the guidance document.

The Crown Estate Scotland, which reports to The Scottish Government and manages seabed leasing for renewable energy projects out to 200 nautical miles (nm) will soon operate under The Scottish Crown Estate Act 2019. A new round of leasing for offshore wind in Scotland, ScotWind Leasing, will launch soon but applications for ocean energy projects of up to 30 MW are accepted at any time.

WALES

The Welsh Government is committed to unlocking the renewable energy potential from Welsh waters by supporting the delivery of marine energy projects. The Welsh Government has a 70% renewable electricity mix contribution target by 2030, a proportion of which should come from marine sources. For this, the Welsh Government has allocated £100.4m of European Union (EU) structural funding over the next 5 years for marine energy through the WEFO. The fund is aimed at establishing Wales as a centre for marine energy production by increasing the number of wave and tidal energy devices being tested including multi-device array deployments. Most recently, the Welsh Government has awarded €14.9m from the European Regional Development Fund (ERDF) grant to support the next phase of Minesto's tidal commercial development in Wales. Furthermore, the Welsh National Marine Plan was launched in November 2019 to provide significant support for marine energy technologies.

Marine Energy Wales brings together technology developers, research institutions, supply chain and public sector bodies for establishing a sustainable ocean energy industry in Wales. The 2019 developments recently announced through this organisation include:

- A detailed business case for the £60m Pembroke Dock Marine project focussed on lowering the cost of marine energy was signed by the Swansea Bay City Deal's Joint Committee;
- The first wave energy marine licence for Bombora for the deployment and testing of their wave energy technology in Wales;
- A new €4.2m Wales-Ireland cross-border project aiming to boost the marine energy industry in both the regions; and

- More than £12m of EU funding to support the next stage of Swansea-based Marine Power Systems' project to create and launch an underwater device capable of generating clean, affordable and reliable energy in Wales and around the world.

The Marine Centre Wales, which opened in 2018 with £5.5m funding, and the Marine Energy Engineering Centre of Excellence continues to support the Welsh marine sector with resources, skills and collaboration.

MARINE ENERGY COUNCIL

The UK Marine Energy Council (MEC) was formed in 2018 by a collaboration of the leading wave and tidal developers, in order to engage with the Government and other stakeholders as a unified sector. The Council is comprised of representatives from the industry and those from leading industry associations Renewable UK, Scottish Renewables, Marine Energy Wales and the Offshore Renewable Energy Catapult, including members from technology and project developers, supply chain companies and consultants. The objectives of the MEC are to progress from the ORE Catapults cost reduction advisory group, encouraging collaboration across the sector and supporting the policy positions for delivery of marine renewables. In 2019, the MEC, along with Scottish Renewables, published the UK Marine Energy 2019 report that highlights the potential economic and low carbon benefits from government investment in the UK's tidal and wave power sectors.

The report proposes two new revenue support models: Innovative Power Purchase Agreements (IPPA) and Innovative Contracts for Difference (ICFD) aiming to increase the industry's cost competitiveness and deliver projects in the UK.

The Marine Energy Council will be formally incorporated in 2020, leading on developing the sector both in the UK and internationally and delivering a work programme to support the growth of the wave and tidal sector through the development of a UK market.

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. Ocean energy technologies are however yet to gain a CfD through the competitive auction process.

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. The third round of auctions opened in May 2019 delivering record low price for offshore wind; clearing at a price of £39.650/MWh for year 2023/24 and £41.611/MWh for year 2024/25. The announced price was 30% lower than the strike price of £57.50/MWh announced in the previous 2017 CfD auction. Twelve projects, of which six offshore wind, four remote islands wind and two-advanced conversion technology projects secured the contracts. This opens up the possibility for offshore wind contributing heavily towards achieving the Net-Zero target by 2050, but at the same time poses challenges to other low-carbon technologies like ocean energy to match similar cost reductions. A breakdown of the outcome by technology, year and clearing prices (2012 prices) is shown in the Table below:

Results of third round of CfD auctions

Technology		2023/24	2024/25	Total Capacity (MW)
Advanced Conversion Technologies	£/MWh	39.65	41.611	33.60
	MW	27.50	6.10	
Remote Island Wind	£/MWh	39.65	41.611	275.22
	MW	225.72	49.50	
Offshore Wind	£/MWh	39.65	41.611	5466.00
	MW	2612.00	2854.00	

Public Funding Programmes

In the last few years, the UK Government has made available some public funding alternatives to support the development of the ocean energy sector. Some of these programmes and initiatives are described in this section.

UK Research and Innovation (UKRI)

In operation since April 2018, UKRI brings together seven research councils to support and coordinate research and innovation in the UK. Independently chaired, UKRI has a £6 billion budget funded primarily through the Science Budget by 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). The UKRI provides a range of funding opportunities to individuals and groups in pursuit of excellent innovation and research. In the recent year, the UKRI announced funding calls in the fields of healthcare, circular economy, marine resources, climate resilience etc. In November 2019, the UKRI rolled out invitations for the role of a Champion in Sustainable Management of UK Marine Resources (SMMR). The programme supported by NERC and ESRC in partnership with the Department for Environment, Food and Rural Affairs (DEFRA) and Marine Scotland, shall provide a fund of £12.4m.
https://www.ukri.org/

Innovate UK

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

Wave Energy Scotland

WES – fully funded by the Scottish Government – is taking an innovative and unique approach to the development of wave technology. WES funds the progression of innovative technology towards commercialisation through stage-gate funding. Stages of R&D activities guide projects from concept to prototype testing. Funding is allocated within distinct technology categories, covering various subsystems, overall wave energy devices, materials and manufacturing.
https://www.waveenergyscotland.co.uk/

Research & Development

This section contains an overview of the primary research institutions and their core project activity in 2019.

Key R&D Institutions

Supergen Offshore Renewable Energy (ORE) Hub

Established in July 2018 with £5m of funding from the EPSRC, the Supergen ORE Hub is coordinated by the University of Plymouth and brings together the expertise from multiple UK institutions including University of Edinburgh, University of Aberdeen, University of Exeter, University of Hull, University of Manchester, University of Oxford, University of Southampton, University of Strathclyde and University of Warwick. On June 2019, it was awarded another £4m to bring together research institutions across the UK to align activity, progress the sector to ambitious levels while cultivating a 'research landscape'. In its first year of operation, the Hub held an Early Career Researcher (ECR) networking event in May 2019 in Glasgow where they covered the ORE Research Landscape developed by the Hub. Launched in November 2019, the interactive Research Landscape is a justified and collaborative interactive map of sector needs from a technological, funding and ecological perspective made for public consumption. The Hub also held its second Annual Assembly on November 2019 at the University of Strathclyde where the latest opportunities, challenges and research within offshore renewable energy technologies were explored. To date, the Hub has awarded around £1m to UK universities to advance ambitious research projects in the offshore renewable energy sector.
https://www.supergen-ore.net/

The ORE Catapult

Offshore Renewable Energy (ORE) ORE Catapult is the UK's flagship technology and innovation research centre, combining research, development, demonstration and testing facilities with leadership, industrial reach

and engineering expertise. ORE Catapult accelerates design, deployment and commercialization of renewable energy technology innovation. By the end of financial year 2018/2019, ORE Catapult had supported 801 Small Medium Enterprises (SMEs) and engaged in 469 academic collaborations and 648 industry collaborations. Currently, ORE is involved in the Tidal Stream Industry Energiser (TIGER) project and the Ocean Energy Scale-Up Alliance (OESA) partnership.
https://ore.catapult.org.uk/

Key R&D Projects

Enabling Future Arrays in Tidal (EnFAIT)

Funded by EU Horizon (H2020), the Enabling Future Arrays in Tidal (EnFAIT) project is a €20.2m project, which began in July 2017 and will run until June 2022. Led by Scottish tidal energy developer Nova Innovation, the project is a partnership of nine European companies and academic partners. EnFAIT builds on Nova Innovation's existing operational tidal array in the Bluemull Sound, in Scotland's Shetland Islands. 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 2019, the project achieved a world first by recovering three turbines from the site before servicing and redeploying all three turbines within one month. EnFAIT also demonstrated the local economic benefits that can be achieved by tidal energy with more than 60 Scottish companies in the project supply chain. The next three turbines will be installed in 2020/21.
https://www.enfait.eu/

Deploying Nova Innovation Turbine at Bluemull Sound (Source: Nova Innovation)

DTOceanPlus

The EU H2020 funded DTOceanPlus will develop and demonstrate a suite of second-generation advanced design tools for the selection, development, and deployment of ocean energy systems. This builds upon the previous EU funded DTOcean project, which produced the first generation of freely available open-source design tools for wave and tidal energy arrays. The integrated tools will be demonstrated in the setting of real-world technology deployment projects, with access to these projects being provided by the project's industrial and commercial partners. The project is led by Tecnalia and comprises 18 EU partners including, from the UK The University of Edinburgh, Wave Energy Scotland, Energy Systems Catapult, Orbital Marine Power, and Nova Innovation.
https://www.dtoceanplus.eu/Tools

Tidal Turbine Power Take-Off Accelerator (TIPA)

The TIPA project focused 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%. Completed in late 2019, TIPA was led by Nova Innovation and funded by EU H2020. The project consortium comprised six European partners (both academic and industrial) including University of Edinburgh. The project included 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. The PTO successfully completed the accelerated onshore testing phase at RWTH Aachen University during summer 2018 and the in-sea testing phase in spring 2019. Cost savings achieved by the project were estimated at 29% – exceeding the 20% target.
https://www.tipa-h2020.eu/

Floating Tidal Energy Commercialisation (FloTEC)

The FloTEC project, led by Orbital Marine Power and funded by the EC's H2020 programme, is an ongoing project running from January 2016 to February 2021. Building on the success of their existing 2 MW floating tidal technology, the SR2000, the FloTEC project is focussed on the design, construction and deployment of Orbital's upgraded technology. The 2 MW Orbital O2 device will be deployed at the EMEC in 2020 to demonstrate how floating tidal systems can provide low-cost, high-value energy to the European grid mix.
www.flotectidal.eu

Second Generation Technologies in Ocean Energies (Ocean_2G)

Funded by the EC's Horizon 2020 programme and managed by Magallanes Renovables, the Ocean_2G project focused on testing, validating and pre-certifying Magallanes' second generation 2 MW tidal energy platform solution, the ATIR. The project undertook a number of key innovations followed by a series of test programmes to demonstrate the operational performance of the prototype in open water conditions in Vigo, and then at EMEC where it was deployed in early 2019.
www.ocean-2g.eu

Strategic Environmental Assessment of Wave energy technologies (SEAWave)

The SEAWave project, co-ordinated by EMEC, aims to address long-term environmental concerns around the deployment of wave and tidal energy converters in the marine environment. The project aims to adopt multi-WEC environmental monitoring campaigns developed through gap analysis on WECs demonstrated in Scotland. The findings from the comprehensive environmental demonstration strategy will be distributed across various European networks to help understand the potential impacts of wave energy deployments. The project is co-funded by the European Maritime and Fisheries Fund (EMFF) of the EU and is supported by a diverse range of project partners across UK, Portugal, Finland, Belgium, Sweden and Ireland.
www.seawaveproject.com

Ocean Power Innovation Network (OPIN)

A cross-sectoral and cross-regional collaboration for offshore renewable energy SMEs, the OPIN is a 3-year initiative from 2019 to 2021. It is led by the Sustainable Energy Authority of Ireland (SEAI) and is represented by Scottish Enterprise (SE) and ORE Catapult as the UK partners. It has a total budget of €2.6m, where Interreg North West Europe (NWE) from the European Research and Development Fund (ERDF) provides €1.5m of financial support. The OPIN project plans to support around 100 companies by transferring already established expertise, capabilities and products from mature proven sectors into the ocean energy sector and thus reduce cost and initiate technology development. The partnering countries involved in this project include the UK, Belgium, France, Netherlands and Germany.
https://www.nweurope.eu/projects/project-search/opin-ocean-power-innovation-network/

Tidal Stream Industry Energiser (TIGER)

Led by ORE Catapult, the TIGER project is an ambitious €46.8m project running from July 2019 to June 2023 and has been recently approved by the France-England programme. With ERDF providing a fund of €28m, the project falls within the category for low-carbon technologies of the Interreg France (Channel) England Programme. It aims to develop cross-regional partnerships while developing, testing and demonstrating new technologies, installing up to 8 MW of new tidal capacity around the Channel region leading to new product and service development. As the biggest project across all Interreg programmes, it will establish tidal stream energy as a cost-effective source while driving growth within the energy mixes of France and the UK.
www.InterregTIGER.com

Ocean Energy Scale-Up Alliance (OESA)

Led by the Dutch Marine Energy Centre (DMEC), the OESA is a 3-year project running from January 2019 to December 2021. With a total budget of €6.2m, where Interreg NWE provides €3.1m of financial support, it is a European partnership of 13 international organisations specialising in offshore engineering, market development, ocean energy testing and technology development. OESA aims to accelerate the development and deployment of ocean energy technologies through an innovative Pilot Accelerator Programme in the North Sea Region (NSR). The project involves accelerating the deployment of 5 scaled-up ocean energy pilots worth 20 MW through strategic partnerships and international collaboration.
https://www.dutchmarineenergy.com/our-projects/ocean-energy-scale-up-alliance-oesa

Integrating Tidal Energy into the European Grid (ITEG)

Funded by the Interreg NWE programme, part of ERDF, the ITEG project has a total budget of €11m and is led by EMEC in Orkney. With EU funding of €6.46m, the project runs from 2017 to 2020 and aims to provide an integrated tidal and hydrogen solution for generating clean energy and, tackling grid export limitations faced in remote areas. Hydrogen will be produced from excess tidal capacity. With project partners from the UK, France, Belgium and the Netherlands, the project aims to drive down the costs of pre-commercial ocean energy demonstration by producing hydrogen using an AREVA H2Gen electrolyser, powered by Orbital's 2 MW O2 - the next generation floating tidal energy converter.
www.nweurope.eu/ITEG

EMEC Caldale substation and hydrogen plant (Source: EMEC)

Wave Energy Scotland (WES)

In 2019, WES continued to deliver strong progress through its stage-gate research, development and innovation programme, awarding £9m to 11 wave energy technology projects. In January 2019, it awarded £7.7m to two companies for building and deploying fully functional pilot devices. Both projects are on track for deployment in Scottish seas in 2020,

having recently signed construction contracts with the supply chain. WES continues to advance the maturity of power conversion systems, with 5 power take-off technologies now demonstrated at large-scale and an additional £1m applied to two control system design projects. To aid deployment and retrieval of wave energy device demonstrators, WES recently announced £460k to begin the development of Quick Connect Systems, successfully engaging further expertise from mature engineering sectors. The WES programme has now awarded nearly £40m to 95 projects and continues to be a driving force in the wave energy sector.

Funding Ocean Renewable Energy through Strategic European Action (FORESEA)

EMEC has led the €11m Interreg NWE project, FORESEA, since it was launched in 2016. Now nearing completion, the project has been hailed an overwhelming success and this year was nominated for the EU Sustainable Energy Week Citizens' Awards 2019. Having enabled 29 technologies to deploy across four European test centres (EMEC, DMEC, SEM-REV and SmartBay), FORESEA has enabled more ocean energy technologies to be tested offshore than any other project, including CorPower Ocean, Orbital Marine Power, Naval Group and Whitford. With the project ending this year, EMEC have launched two follow on projects to further support real-sea testing: OceanDEMO and Blue-GIFT.
https://www.nweurope.eu/projects/project-search/funding-ocean-renewable-energy-through-strategic-european-action/

Ocean DEMO

Launched in January 2019 and funded by Interreg North-West Europe, the Ocean DEMO project is a €13m project. Built upon the FORESEA project, it aims to accelerate ocean energy's transition from single prototype to multi-device farms by providing free access to key European test centres: EMEC, DMEC, SEM-REV and SmartBay. Under its first call that ended in July 2019, twelve offshore renewable developers were awarded the opportunity to participate in the project. The second call opened on September 2019 and will close in January 2020.
www.oceandemo.eu

Selkie

Launched in 2019, Selkie is funded by the EU's Ireland-Wales co-operation programme and is led by University College Cork in partnership with Swansea University, Marine Energy Wales, Menter Môn, DP Energy Ireland and Dublin-based Gavin and Doherty Geosolutions.

The 4.2M Euro project will see the development of a streamlined commercialisation pathway for the marine energy industry by establishing a cross-border network of developers and supply chain companies in Ireland and Wales. Multi-use technology tools and models will be created and trialled on pilot projects before being shared across the sector.

SEACAMS2

The SEACAMS2 project supports developing economic opportunities in Low Carbon, Energy and Environment through specialisation in commercial application of research and innovation in marine renewable energy (MRE), climate change resilience and resource efficiency in Wales. The £17m project, a partnership between Bangor University and Swansea University, is part-funded by the European Regional Development Fund and focuses on the convergence region of Wales.

Technology Demonstration

TEST CENTRES & DEMONSTRATION ZONES

Offshore test centres and demonstration zones enable the deployment of wave and tidal energy devices for R&D. A selection of these facilities are described below.

The European Marine Energy Centre (EMEC)

EMEC remains the world's only United Kingdom Accreditation Service (UKAS) accredited test and research centre focusing on wave and tidal power development. Apart from supporting the demonstration and validation of ocean energy technologies, EMEC also works on projects related to floating offshore wind, green hydrogen and energy systems. To support demonstration plans of EMEC's tidal energy clients, Crown Estate Scotland granted an extension to EMEC's lease for the Fall of Warness, now running until 2040. At EMEC's Billia Croo wave test site, Microsoft continued testing their subsea data centre, powered by Orkney's renewable electricity and cooled by the ocean. In March, EMEC launched the €31 million AFLOWT project to accelerate the uptake of floating offshore wind that will utilise the offshore renewable expertise built up over the years from demonstrating wave and tidal technologies. EMEC also launched a number of new support programmes for offshore energy technologies in 2019, including OceanDEMO and Blue-GIFT. EMEC is also supporting the development of other test facilities

around the globe, including Ireland, China, South Korea and the USA, and leads the International WaTERS (Wave and Tidal Energy Research Sites) network.
http://www.emec.org.uk/

Wave Hub

Wave Hub is a pre-installed grid-connected site approximately 10 nautical miles (16km) 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. The test site is currently finalising plans to accommodate Floating Offshore Wind alongside wave energy technologies.
https://www.wavehub.co.uk/

FaBTest

FaBTest is a 2.8km^2 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 9 metre 1-in-100 year return period significant wave height. In 2019, Marine Power Systems (MPS), followed by AMOG Consulting Ltd., more recently decommissioned their 'WaveSub' mooring system and 'AEP' wave energy converter, respectively, after testing and successfully generating power at FaBTest.
http://www.fabtest.com/

Marine Energy Test Area (META)

META is a newly established test site developed by the Marine Energy Wales in the Milford Haven Waterway in Pembrokeshire, which has recently identified seven potential sites. The Area comprises a variety of sites with consent and grid connection, which will facilitate testing of component, sub-assembly and single-device stages. META aims to de-risk full-scale deployments, support innovation of global marine energy products and services, add value to the UK test centre network while supporting supply chain initiatives. Development of the site is informed by strategic advice given by established test-centres EMEC and Wave Hub. It has recently secured a £1.9m funding from ERDF, Coastal Communities Fund and Swansea Bay City Deal. META Phase 1 was officially opened in September 2019.
https://www.marineenergywales.co.uk/meta/

Morlais Tidal Demonstration Zone

The site in West Anglesey was primarily setup for its tidal resource and access to local infrastructure. The 35 km^2 site is being sub-let for testing and demonstrating activities alongside some of the first array scale commercial projects. This is a £33m project, which had been awarded £4.5m of EU and Welsh Government funds. The site is currently in the process of securing consent for the development of the demonstration zone following which, necessary infrastructure would be put in place for testing commercial deployment if tidal stream projects. Nova Scotia based Big Moon Power, signed a deal on May 2019, to commercially deploy their tidal energy technology at the site.
http://www.morlaisenergy.com/

ARRAYS AND DEMONSTRATION PROJECTS

This section is a non-exhaustive list of key projects tested, installed in the sea and operating in 2019.

MeyGen

The MeyGen array is owned and operated by SIMEC Atlantis Energy in Scotland's Pentland Firth. In December 2019, the MeyGen project confirmed it has surpassed 23 GWh of generation onto the grid since project commencement. With no offshore maintenance interventions in 2019, the total system availability from January-October (latest available at the time of writing) averaged around 90%.
https://simecatlantis.com/projects/meygen/

MeyGen deployment (Source: SIMEC Atlantis Energy)

Magallanes Renovables

Spanish tidal developer Magallanes Renovables' second-generation tidal turbine device, the ATIR, was successfully deployed at EMEC's grid-connected Fall of Warness tidal test site in February 2019. Funded by the Fast Track to Innovation pilot scheme, part of the EU's H2020 research and innovation programme, the device generated its first electricity into the UK national grid at EMEC in March 2019. It is now undergoing further testing to demonstrate its operational performance before being commercially available.
http://magallanesrenovables.com/en/proyecto

Marine Power Systems (MPS)

Swansea-based wave developer Marine Power Systems (MPS) successfully concluded testing and sea trials for WaveSub, its prototype wave energy generator after running it for a period of 12 months at FaBTest, Cornwall. This was a £5.5m project, which has received £3.5m Welsh European Funding Office & Welsh Government funding. More recently, MPS has been awarded £12.8m EU funds to support the manufacture and testing of a full-scale WaveSub wave energy converter that would allow the company to develop a full-scale prototype for providing renewable energy in and around Wales. Soon after this announcement, MPS received another £4.3m by the European Regional Development Fund (ERDF) to launch and accelerate the development programme of the DualSub technology, a floating offshore wind and wave technology that would allow for energy generation in deep-water locations.
https://www.marinepowersystems.co.uk/

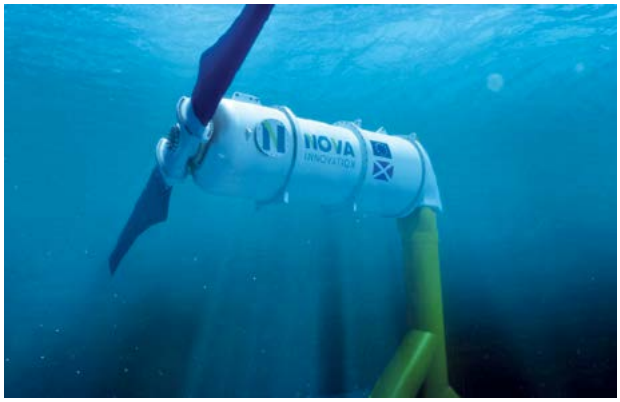
WaveSub towed out of Falmouth towards FaBTest (Credit MPS)

Minesto

Swedish marine energy developer Minesto received €14.9m of EU funding in May 2019, for the commercial development of Minesto's tidal energy scheme in Wales. After being upgraded to an enhanced PTO system, Minesto's DG500 kite system was commissioned at Holyhead Deep site offshore North Wales in September 2019. Minesto later retrieved the system back to carry out further tests and improvements at the site.
https://minesto.com/

Nova Innovation

Nova Innovation was granted an extension to their existing seabed lease by Crown Estate Scotland, significantly increasing the capacity of the site from 0.5 MW to 2 MW. This extension will enable Innovation to progress their EnFAIT project with the installation of three additional Nova M100 turbines, each rated at 0.1 MW. 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. By December 2019, Nova Innovation's turbines had accumulated over 20,000 hours generating energy to the Shetland grid. The Scottish tidal developer has also been granted licence to deploy a tidal array of 15 new turbines worth 1.5 MW starting 2020 in the Bay of Fundy area of Nova Scotia, Canada. The project will last until 2023 and will provide power to 600 homes.
https://www.novainnovation.com/



Nova Innovation's Underwater Turbine (Source: Nova Innovation)

Planned Deployments

This section contains a non-exhaustive summary of wave and tidal projects expected to be deployed in 2020.

WAVE

Bombora Wavepower

Australian wave energy developer Bombora Wavepower secured a £10.3m ERDF grant in 2018 to support the design and testing of a fully submerged membrane-style wave energy convertor at Pembroke Dock. It is currently in the process of designing, building, deploying, testing and validating its 1.5 MW mWave wave energy converter. In October 2019, the developer received the first Marine Licence for a wave energy device in Wales, for the deployment and testing of their mWave wave energy technology off the coast of Pembrokeshire, Wales.
https://www.bomborawave.com/

AWS Ocean Energy

AWS has developed a fully submerged point absorber named the 'Archimedes Waveswing', which will be deployed at scale in the EMEC Scapa Flow site in 2020 as part of the WES programme. AWS was awarded £4.4m from WES to develop their prototypes before deploying and testing them in Orkney.
http://www.awsocean.com/

Mocean Energy

Mocean's 'Blue Horizon' technology is a floating hinged raft, whose innovation is in its geometry. Its wave channel features enable it to generate more than three times the power of traditional rafts. The technology will be deployed at scale in Orkney waters as part of the WES programme. Mocean was awarded £3.3m from WES to further develop their prototype before deploying and testing them in Orkney.
https://www.mocean.energy/

Laminaria

With the production of Laminaria's full-scale 0.2 MW LAMWEC wave device underway, deployment is planned at EMEC's Billia Croo site in 2020 to 2021. 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.
http://www.laminaria.be/lamwec.html

Wello Oy

After seven years of many successful deployments, trials and lessons learnt from the testing period of the first Penguin WEC - WEC1, Finnish based company Wello Oy has ended the CEFOW (Clean Energy From Ocean Waves) project in Scotland. The learnings from WEC1 have been fed into the WEC2 design which was towed from Estonia to Orkney for deployment at EMEC. The device is currently berthed at Hatston Pier in Kirkwall, however with the early closure of the EU-funded CEFOW project, Wello are considering their options regarding deployment locations.
https://wello.eu/

TIDAL

Orbital Marine Power

In 2019 Orbital Marine Power, commenced construction of their optimised production model, the Orbital O2 2 MW, for deployment at EMEC in 2020. The O2 will feature two 20 m rotor diameters, the largest swept area of a single tidal energy converter to date, - blade pitch control for floating tidal energy and simplified onsite nacelle access through a new 'gull wing' leg retraction system. Orbital Marine Power received £7m of peer-to-peer Abundance investment in October 2018 to build the production model. The Orbital O2 is funded under H2020 FloTEC (Floating Tidal Energy Commercialisation), with funding also from Interreg North-West Europe ITEG and the Scottish Government's Saltire Tidal Energy Challenge Fund. Orbital Marine Power is also a project partner for the ambitious TIGER project, the largest marine energy R&D collaboration by value to date.
https://orbitalmarine.com/

Nova Innovation

In 2020/21, Nova Innovation plans to install three more M100 0.1 MW turbines alongside the three turbines currently in place at Bluemull Sound in Shetland. After a period of operation, the devices will be moved within the array in order to investigate turbine wake interactions for the first time in an in-sea tidal array.
https://www.novainnovation.com/

Relevant National Events

Some relevant events for the ocean energy sector that took place in the UK in 2019 include:

- 4 April 2019, Marine Energy Wales Annual Conference 2019, Newport
- 15 - 16 May 2019, All Energy 2019, Glasgow
- 9 - 14 June 2019, Ocean, Offshore and Arctic Engineering (OMAE) Conference, Glasgow
- 9 - 10 September 2019, Scottish Renewables Marine Conference 2019, Inverness
- 2 - 4 October 2019, 6th International WaTERS (Wave and Tidal Energy Research Sites) Workshop, Orkney
- 6 November 2019, Supergen Annual Assembly, Glasgow
- 11 - 12 November 2019, International Tidal Energy Summit 2019, London
- 5 December 2019, Wave Energy Scotland Annual Assembly 2019, Edinburgh

The UK will also be hosting some important events in 2020 that are of interest for the ocean energy sector such as:

- 17 - 19 March 2020, Oceanology International 2020, London
- 13 - 14 May 2020, All Energy 2020, Glasgow
- 9 - 19 November 2020, Conference of the Parties 26 (COP 26), Glasgow

USA

Supporting Policies for Ocean Energy

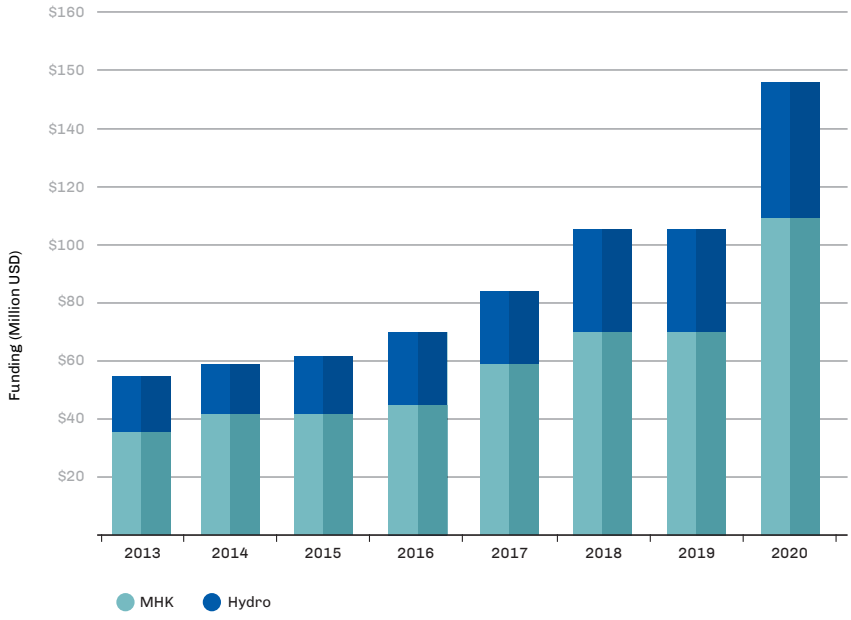
National Strategy

The U.S. Department of Energy (DOE) **Water Power Technologies Office (WPTO)** serves to advance cutting-edge technology to modernize the U.S. hydropower fleet and promote U.S. leadership in ocean and river energy. WPTO aligns itself with Federal goals for ocean resource utilization and works with other agencies, such as the National Science Foundation, the U.S. Navy, and the National Oceanic and Atmospheric Administration to advance Federal ocean priorities. Many of these priorities are encapsulated in a report released at the end of the 2018 calendar year by the Subcommittee on Ocean Science and Technology (a part of the National Science and Technology Council), titled "Science and Technology for America's Oceans: A Decadal Vision"[15]. Ocean energy is featured a number of times throughout the report.

WPTO makes investments that support key technology innovations, mitigate risks, and assists in creating a robust U.S. marine renewable industry by providing funding and technical assistance. 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 tools, services, and technologies that tackle specific challenges hindering development and commercial adoption. More information on WPTO can be found at: water.energy.gov

In 2019, WPTO formally launched a new R&D initiative called ***Powering the Blue Economy*** whose purpose is to understand the power requirements of emerging coastal and off-grid markets that are well-suited to integrate with marine renewable energy to relieve power constraints and promote economic growth within the blue economy. This initiative builds off prior work, including the Marine Energy Technologies Forum: Distributed and Alternate Applications from December 2017 and the release of the Powering the Blue Economy™: Exploring Opportunities for Marine Renewable Energy in Maritime Markets report in March 2019.

Federal funding for WPTO has maintained an upward trend since fiscal year (FY) 2013. FY 2020 funding for WPTO is $148M.



15 https://www.whitehouse.gov/wp-content/uploads/2018/11/Science-and-Technology-for-Americas-Oceans-A-Decadal-Vision.pdf

Other Federal R&D Activities

The Water Power Technologies Office is the primary group covered under this chapter, but other Federal agencies and offices are involved in supporting the deployment of marine renewable energy. For example, 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 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.

The Defense Advanced Research Projects Agency (DARPA) hosted an industry day in May 2019 to kick-off the Manta Ray research program. The goal of the Manta Ray program is to investigate designs of unmanned underwater vehicles (UUVs) that are capable of both long duration missions and large payload capacity. Marine energy systems could play an integral role in this solicitation. More information can be found by searching "Manta Ray" at www.fedbizopps.gov.

Market Incentives

While there are no dedicated marine renewable energy market incentives in the U.S., there are clean energy incentives which may be applicable in some regions. **Clean Renewable Energy Bonds (CREBs)** are federal 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 eight states have voluntary renewable energy goals or targets.

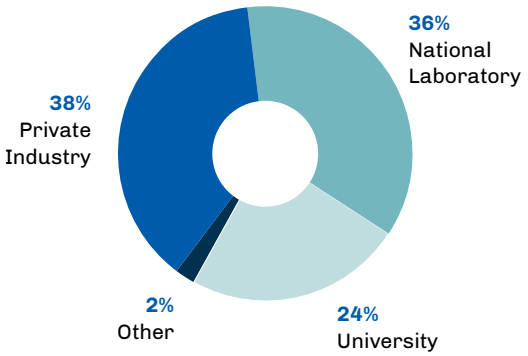
Many states also have **Public Benefit Funds (PBF)**, which are a state-level market support mechanism designed to provide continued support for renewable energy resources, energy efficiency initiatives, and low-income energy programs. The incentives for each PBF vary by state. MHK technologies can also benefit from funding opportunities through non-profits and public-private partnerships, such as the Oregon Wave Energy Trust or Schmidt Marine Technology Partners.

Public Funding Programmes

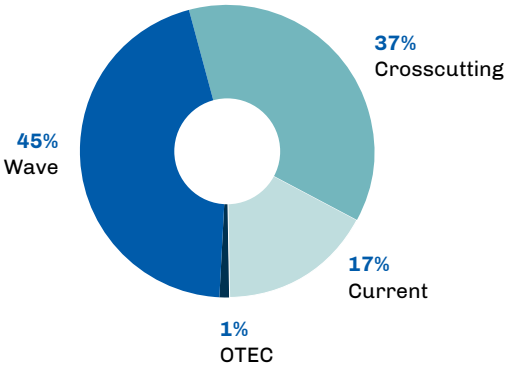
Department of Energy Water Power Technologies Office - Marine and Hydrokinetic Program

Since 2008, WPTO funding awards have been split very evenly among private companies, universities, and the DOE national laboratories. The bulk of WPTO funding awards 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 below).

Percent of total Funding Distribution by Recipient
FY 2008-2018



Percent of total Funding Distribution by Reource Type
FY 2008-2018



Developers can seek DOE WPTO funding through several different competitive funding mechanisms. **Funding Opportunity Announcements (FOAs)** are topic-specific 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 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. DOE also has a **Technology Commercialization Fund** (TCF) which leverages R&D funding in the applied energy programs, paired with private partners, to mature promising energy technologies with high impact potential. Lastly, DOE is also able to run prize competitions which can attract new innovators and investment to specific challenge areas.

WPTO identifies and funds qualified projects within specific topics 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 can be found at: https://energy.gov/eere/water/water-power-funding-opportunities.

To see other examples of all WPTO funded projects, visit the online project database map at: https://www.energy.gov/eere/water/water-power-technologies-office-projects-map.

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, the Wave Energy Test Site 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, including:

- National Renewable Energy Laboratory (NREL)
- Pacific Northwest National Laboratory (PNNL)
- Sandia National Laboratories (SNL)

R&D Highlights

- In January 2019 WPTO awarded $25M in research projects for next-generation marine energy devices. Twelve innovative projects were provided funding to reduce capital costs and tighten the design spiral of new concept testing. Research topic areas include: Early Stage Device Design Research, Controls and Power Take Off Design Integration and Testing, and Dissemination of Environmental Data and Analyses to Facilitate the Marine Energy Regulatory Process.
- In March 2019 WPTO published the report, ***Powering the Blue Economy™: Exploring Opportunities for Marine Renewable Energy in Maritime Markets.*** The report highlights potential markets for marine energy technologies beyond the national electric grid, including applications where marine energy presents unique advantages over incumbent energy technologies. More information available at: https://www.energy.gov/eere/water/downloads/powering-blue-economy-report.

- In March 2019 WPTO announced funding to establish a new testing program for marine energy technologies: the **U.S. Testing Expertise and Access for Marine Energy Research (TEAMER) Program.** TEAMER will be a three-year, $16M program supporting testing and research for marine energy technologies and will provide technology developers (1) access to testing infrastructure; (2) access to world-class experts; and (3), comparable testing protocols and data. In September 2019 WPTO announced the selection of the Pacific Ocean Energy Trust (POET) as Network Director for TEAMER to ensure it runs smoothly.
- In June 2019 WPTO launched the **Waves to Water Prize**, a four-stage competition providing up to $2.5M in cash prizes, the goal of which is to demonstrate small, modular, cost-competitive desalination systems that use the power of ocean waves to provide clean drinking water for disaster recovery and for remote and coastal communities. The ten winners of the first stage of the competition were announced in November 2019. More information can be found at: https://americanmadechallenges.org/oceanobserving/.
- In June 2019 seven small marine energy businesses were selected by WPTO through the Energy Department's **Small Business Innovation Research (SBIR)** program. In this round of funding, recipients received funding to demonstrate the technical feasibility of their respective innovations over the course of a year. The seven recipients were awarded under topics such as pumping and compression, microgrids in remote coastal communities, ocean energy storage, and critical mineral harvesting from seawater.
- In September 2019 WPTO launched the **Marine Energy Collegiate Competition (MECC)** in which student teams will explore innovative marine energy solutions to address power needs across the blue economy. Fifteen teams, selected in November 2019, will identify a promising market within the blue economy and the best marine energy application to address the unique needs of that market. Finalists will then present their design and business cases during the **International Conference on Ocean Energy in Washington**, DC in May 2020.
- In October 2019 WPTO launched the **Marine and Hydrokinetic Graduate Student Research Program**. Administered by WPTO and the Oak Ridge Institute for Science and Education (ORISE), the program is open to full-time doctoral students with a research thesis and/or dissertation at a U.S. institution. The program is designed to advance the graduate student's overall doctoral thesis while providing access to the expertise, resources, and capabilities available at DOE offices, National Laboratories, industry, and other approved facilities where the participant will conduct part of their research. More information here: https://orise.orau.gov/mhk-research-program/.
- In October 2019 WPTO announced grant selections for up to $24.9M in funding to drive innovative, industry-led technology solutions to advance the marine and hydrokinetics industry and increase hydropower's ability to serve as a flexible grid resource. Recipients were selected across four areas of interest as outlined in the funding opportunity announcement, those relating to marine energy include: Low-Head Hydropower and In-Stream Hydrokinetic Technologies, Advancing Wave Energy Device Design, and Marine Energy Center Research Infrastructure Upgrades. Grant recipients include: C-Power (formerly Columbia Power Technologies, Inc.), CalWave Power Technologies, Inc., Stevens Institute of Technology, Ocean Renewable Power Company, ABB Inc., Purdue University, and IDOM, Inc.
- In November 2019 WPTO, in partnership with the National Oceanic and Atmospheric Administration (NOAA) Integrated Ocean Observing System (IOOS), launched the **Powering the Blue Economy: Ocean Observing Prize**. The competition will award up to $3M in cash prizes and challenge competitors to develop novel ways of integrating marine energy systems with ocean observing platforms and technologies. More information can be found at: https://americanmadechallenges.org/oceanobserving/.

Technology Demonstration

Projects in the Water

Ocean Power Technologies recently achieved a milestone with the continuous one-year operation of its PB3 PowerBuoy® wave energy converter in the Adriatic Sea. This 3 kW WEC is being used to advance Eni's R&D MaREnergy project, aiming to demonstrate the suitability of wave energy renewable technologies in Oil & Gas operations. The PB3 PowerBuoy® is being used to study integration with subsea technology systems to allow remotely controlled applications such as field development, environmental monitoring, and offshore asset inspection using autonomous underwater vehicles.

Ocean Power Technologies

Ocean Energy is set to begin testing of their recently constructed 500 kW Ocean Energy Buoy at the U.S. Navy's Wave Energy Test Site in Hawaii as of November 2019. The device was built at Vigor Iron Works in Portland, Oregon over the course of 2018 and 2019 and then towed across the Pacific to its testing site in November 2019. The 35-meter device will have a 500 KW HydroAir turbine designed by Seimens. The turbine has its own controls system and has already been successfully tested at sea in Galway Bay, Ireland.

In June 2019, the tiny southwestern Alaska village of Igiugig became the first U.S. tribal entity to receive a Federal Energy Regulatory Commission permit for a water-powered project not connected to a dam. A month later, the Igiugig Village and **Ocean Renewable Power Company** (ORPC), deployed a 35 KW submerged crossflow river current turbine system (RivGen® Power System) into the Kvichak River. This single system could provide up to half of the community's electricity and greatly reduce its dependency on costly diesel fuel. Plans are underway for installation of a second RivGen device in conjunction with smart microgrid electronics and energy storage. When completed, the overall system will reduce Igiugig Village diesel use by 90%.

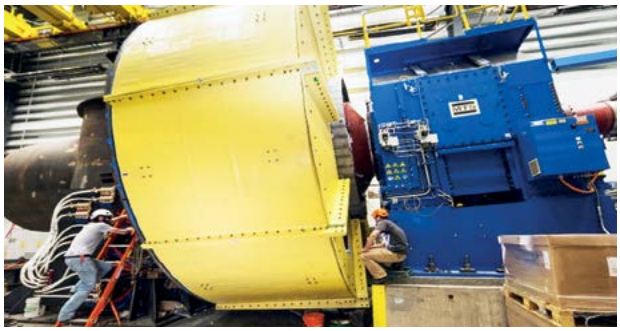
Ocean Energy

Ocean Renewable Power Company

Planned Deployments

C·Power (formerly Columbia Power Technologies), as a result of funding from both the US DOE and US Navy, completed the fabrication drawings for its utility-scale StingRAY H2 WEC and planning for an open-water, grid-connected test of the H2 at the U.S. Navy's Wave Energy Test Site in Hawaii, USA. The device will be fabricated in 2020. A separate project investigating the use of multiple materials for hybrid hull structures—fiber-reinforced plastic and steel—was also completed in 2019, with the testing occurring at the National Renewable Energy Laboratory in Colorado, USA. A project for the design of the next-generation StingRAY H3 will be initiated in 2020. Also in 2019, C-Power initiated the design of a watt-scale and two kilowatt-scale WECs for the ocean observation, commercial and defense sectors—the dataRAY, SeaRAY, and TigerRAY WECs, respectively—which will be tested in 2020 at the PacWave-North test facility of the Oregon, USA.

Verdant Power'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



C·Power

the TriFrame system in the spring of 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.

Oscilla Power is developing a two body multi-mode point absorber WEC called the Triton. The company has completed extensive testing at scale and is working towards a commercial scale system through a number of WPTO-funded programs. The company has recently finalised the drivetrain design for this system and will complete independent laboratory testing in early 2020. Concurrently the company is finalizing construction of a 10 m x 7 m 100 kW variant called Triton-C which is scheduled for testing in the summer of 2020 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.

Verdant Power

Relevant National Events

In April 2019, Washington, D.C. hosted **Waterpower Week**, an annual event that includes the National Hydropower Association's Annual Conference, the International Marine Renewable Energy Conference. The three-day conference had discussions on non-grid scale markets, modelling, cost reduction strategies, and advanced controls, just to name a few.

Information on the event, including some presentations can be found at: https://www.energy.gov/eere/water/articles/wpto-water-power-week-washington-2019

The U.S. Department of Energy is a strategic partner for the upcoming 2020 International Conference on Ocean Energy (ICOE) in Washington, D.C. As a sponsor, the Energy Department's Water Power Technology Office will assist in the development of content and programs, including its first-ever Marine Energy Collegiate Competition. The event is scheduled to take place on May 19-21, 2020 in Washington, D.C.

04
APPENDICES

APPENDIX 1

Membership of the Executive Committee

CABINET 2019

CHAIRMAN
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

Country	Delegate	Alternate
Australia	Dr. Mark Hemer CSIRO Oceans and Atmosphere	Mrs. Stephanie Thornton Australian marine Energy Taskforce (AMET)
Belgium	Dr. Ludovic Mouffe Federal Public Service Economy	Dr. Vicky Stratigaki Ghent University
Canada	Mr. Ghanashyam Ranjitkar Natural Resources Canada	Mrs. Monika Knowles Natural Resources Canada
China	Mr. Peng Wei National Ocean Technology Center, SOA	Mr. Wang Ji National Ocean Technology Center
Denmark	Mrs. Karina Remler Energistyrelsen, EUDP	Dr. Kim Nielsen Ramboll
European Commission	Dr. Ir. Matthijs SOEDE EC DG Research & Innovation	Dr. Davide MAGAGNA EC DG Joint Research Centre
France	Mr. Yann-Hervé De Roeck France Energies Marines	Mr. Kelly Cayocca France Energies Marines
Germany		Mr. Jochen Bard Fraunhofer Institute for Energy Economics and Energy Systems Technology IEE
India	Dr. M. A. Atmanand National Institute of Ocean Technology	Dr. Purnima Jalihal National Institute of Ocean Technology
Ireland	Mr. Declan Meally Sustainable Energy Authority of Ireland	Mrs Patricia Comiskey Sustainable Energy Authority of Ireland
Italy	Mr. Luca Benedetti Gestore dei Servizi Energetici (GSE)	
Japan	Dr. Yasuyuki Ikegami Institute of Ocean Energy, Saga University	Dr. Shuichi Nagata Institute of Ocean Energy, Saga University
Korea	Mr. Man Wook Hoe Ministry of Oceans and Fisheries	Dr. Jin-Hak Yi Korea Institute of Ocean Science & Technology
Mexico	Mr. Rodolfo Silva Casarín CEMIE – Océano	Dr. Juan Carlos Alcéreca Huerta CEMIE – Océano
Monaco	HE Bernard Fautrier Government of the Principality of Monaco	Mr. Sébastien Lubert Fondation Prince Albert II de Monaco
Netherlands	Mr. H.W.Boomsma Ministry of Economic Affairs	Mr. H.P.E.M. Reijnders Netherlands Entreprise Agency
New Zealand	Mr. Gareth Gretton AWATEA	
Norway	Mr. Harald Rikheim Norges Forskningsråd	
Portugal	Prof. Luis Gato Instituto Superior Técnico (IST)	Prof. António Falcão Instituto Superior Técnico (IST)
Singapore	Prof. Subodh Mhaisalkar Energy Research Institute	Dr Srikanth Narasimalu Energy Research Institute
South Africa	Dr Thembakazi Mali SANEDI	
Spain	Mr. Luis Hilario Alonso Mijares Ministerio de Industria, Turismo y Comercio	Mr. Yago Torre-Enciso BIMEP
Sweden	Ms. Maria Olsson Swedish Energy Agency	Mr. Lars Karlbom Swedish Energy Agency
UK	Mr. Trevor Raggatt Department of Energy and Climate Change	Mr. Henry Jeffrey The University of Edinburgh
USA	Mr. Tim Ramsey U.S. Department of Energy	Mr. David Hume Pacific Northwest National Laboratory

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
36	26 - 27 March 2019	Riviera Maya	MEXICO
37	2 - 3 October 2019	Dublin	IRELAND

Next Exco Meetings

38	20 - 22 May 2020	Washington, D.C.	USA
39	5 - 6 November 2020	Tasmania	AUSTRALIA

CONTACTS

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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).