ANNUAL REPORT

AN OVERVIEW OF OCEAN ENERGY ACTIVITIES IN 2017

OES OCEAN ENERGY SYSTEMS

iea Energy Technology Network

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Published by: The Executive Committee of Ocean Energy Systems
Edited by: Ana Brito e Melo and Henry Jeffrey
Designed by: Formas do Possível . Creative Studio | www.formasdopossivel.com

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CHAIRPERSON'S MESSAGE

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

A warm welcome to the 2017 OES Annual Report and I trust that you will find it informative and useful.

I would like to begin by thanking all member countries for their contributions to this report. The country reports included here convey that 2017 has been a landmark year in ocean energy. Cumulative ocean energy capacity has doubled worldwide from less than 12 MW in 2016 to over 25 MW in 2017. In Scotland, two tidal stream arrays have deployed their first phase of development. Successful testing programmes have seen prototype wave and tidal devices and sub-systems deployed globally. In Spain, the first full year of continuous operation of a floating wave energy device occurred with the OCEANTEC device deployed at the BiMEP test site.

Our 2017 feature article is an interview with Dr Andrea E. Copping discussing the environmental issues associated with ocean energy and the challenges occurring as larger-scale commercial developments are installed. Her discussion of the potential transfer of knowledge from other marine industries and the limitations of applying this knowledge to mitigate environmental risks within the ocean energy sector is particularly thought provoking.

Some key achievements for wave and tidal projects are discussed throughout this report. The UK has achieved a key milestone this year with the successful deployment and grid connection of the first phase of two tidal stream arrays, namely the 6 MW first phase of the Atlantis Tidal Ltd MeyGen project in Scotland's Pentland Firth and the 300 kW phase 1 of the Nova Innovation Ltd Bluemull Sound project. Both arrays have plans for further expansion in the coming years. In 2017 the wave energy sector has also seen good progression on the structured innovation approach to wave energy development, with many successful testing programmes completed including the Danish Floating Power Plant (FPP) project and the Norwegian Wave-EL project. In addition to this, we have seen many useful international collaborations develop, particularly between the USA and Europe. However, globally we are still waiting on clear market signals for wave and tidal projects. Such market signals are vital for the industry to progress towards commercialisation.

In terms of the OES, 2017 saw the publication of our Vision for International Deployment for Ocean Energy, targeting 300 GW of installed capacity worldwide by 2050. Two new OES tasks were launched in 2017 on Stage Gate Metrics for Ocean Energy and Numerical Code Validation for Tidal Energy. Additionally, a new study on the Cost of Energy was included as a continuation of the work completed in Task 11. For 2018 we also welcome two new vice chairs: Annie Dallman from the USA and Yann-Hervé De Roeck from France.

Finally, I'd like to thank Jose Luis Villate for all of his excellent work as chairman and vice-chairman over the last number of years. Many thanks also to our Executive Secretary Ana Brito e Melo for all of her hard work in putting this report together.

EXECUTIVE SUMMARY

DR. ANA BRITO E MELO
OES Executive Secretary

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

INTRODUCTION

Ocean Energy Systems (OES) is the short name for the **Technology Collaboration Programme on Ocean Energy Systems** under the International Energy Agency (IEA). This Annual Report presents an overview of the activities undertaken within OES in 2017, as well as updated country reviews prepared by the Delegates.

The year 2017 marked the beginning of the fourth 5-year mandate (2017 – 2022) of the OES.

The Strategic Plan for this next five years continues to be the guiding document for the OES work programme. The development of ocean energy has been slower than expected. A longer-term vision is required to see the development of ocean energy to the stage where it becomes a viable, cost-effective and reliable alternative to other forms of renewable energy. The added value of the OES arises from good, truly international cooperation. OES is the only intergovernmental, multinational organization in the ocean energy sector, independent of any commercial interests and composed of active members, that encompass the full range of interests from government policy to industry developments. For this new work period, OES will bring added value to national activities by coordinated efforts on priority topics for the whole sector and by delivering clear key technology policy messages to decision makers.

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 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 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 2017. It synthesizes the main achievements in the OES collaborative activities and presents

relevant policies and projects by each OES member country. It also includes, as in previous years, an interview on a specific topic, this year about environmental issues on ocean energy: Andrea Copping, coordinator of the work done under Task 4 (known as Annex IV) gives her views to six questions from OES.

OES KEY ACTIVITIES IN 2017

The OES held two ExCo Meetings in 2017: The 32nd and 33rd meetings were convened in the Principality of Monaco (9 – 10 May 2016), and Chennai, India (14 - 15 November 2017). The meeting in Monaco was organised for the occasion of the International event on Renewable Energies in Monaco, EVER2017, organised by Monaco Sustainable Development, a forum of specialists coming from universities and industries, involved in R&D projects in the area of ecological vehicles or renewable energies. In India, the OES Delegates participated as well in the workshop *'Harnessing Energy from the Oceans - A Global Scenario'*, organised by the Indian Institute of Ocean Technology (NIOT), in Chennai, in which an inaugural session of the Indian wave powered navigational buoy and OTEC facility were organised.

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

The main achievements in these Tasks are presented in chapter 2.

Task 4 (known as Annex IV) continued to collect information on new wave and tidal projects and for ongoing research studies stored as metadata in *Tethys*, the online knowledge management system. During 2017, Annex IV co-hosted 2 workshops, 4 webinars and 2 online expert forums. In 2017, one more Short Science Summary - "Entanglement with Marine Renewable Energy Mooring Lines" - was created under Annex IV in addition to the existing 8 short quick-reference one-page documents accompanying the "State of the Science" (SOS) report summarizing the current understanding of environmental risks and uncertainties between ocean energy devices and the marine environment.

The Web Gis Database for ocean energy developed under **Task 6** and maintained by Fraunhofer IEE, continues to expand and to increase user interactions.

Task 7 on the Cost of Energy for Ocean Energy Technology was mentioned as one important topic that the ExCo should continue to address and it was suggested further progress in order to build confidence in the ocean energy sector.

Under **Task 9** the "International Vision for Ocean Energy" brochure was released in early 2017 and also translated into Spanish.

Task 10 on wave energy modelling verification and validation has progressed in 2017 with the publication of a joint scientific paper and organisation of 4 meetings and webinars.

A group of 8 Member Countries - China, France, India, Korea, Japan, Mexico, Monaco and Singapore - have been working together on OTEC issues under **Task 11** and a first webinar was organised by China during the year.

In 2017, the following two new tasks were initiated:

- **Task 12:** To establish a common international stage gate metrics framework to be used by technology developers, investors and funders;
- **Task 13:** To validate numerical tools for tidal energy.

Further, a number of other topics were discussed as potential new tasks:

- Assessment of the number of jobs related to the development of the ocean energy sector;
- Ocean energy in insular conditions;
- Open water testing to exchange information and experience on all aspects of planning, development, operation, and usage of open-water test facilities.

In 2017, the OES was present in 5 relevant international events in Spain, France, Belgium, UK, Canada and Mexico.

OCEAN ENERGY POLICIES IN MEMBER COUNTRIES

NATIONAL STRATEGIES FOR OCEAN ENERGY

OES countries have different available resources and their own unique energy markets, and therefore distinctive paths for ocean energy development and different policies are followed by each government. Several countries have their national action plans with renewable energy targets, and a few countries specify targets for ocean energy. Worldwide, targets for renewable energies continue to be a primary means for governments to express their commitment to renewable energy deployment. As of year-end 2017, 9 of the 25 members had specific ocean energy targets (see Table 1).

Action plans or strategic documents are intended to set out an agreed vision for the ocean energy sector. These plans usually outline the actions required by both private and public sectors to facilitate the development and deployment of ocean energy technology. As of year-end 2017, 9 of the 25 members had specific strategic documents for ocean energy or key action plans to stimulate R&D on ocean energy (see Table 1).

Roadmaps for the development of ocean energy have been articulated in a number of countries, providing long-term frameworks for developing policies and supporting actions. Some of these roadmaps are technology focused providing a guide for mobilising national efforts down a deployment pathway towards a target. These roadmaps can provide focused and coherent approaches to technology development in the ocean energy sector and their successful implementation depends upon a number of complex interactions between commercial, political and technical aspects. As of year-end 2017, roadmaps have been prepared by 8 countries and the European Commission in order to initiate a debate about the pathway for ocean energy. The pathways are usually analysed in terms of economic competitiveness, employment opportunities and energy security.

MARKET DEPLOYMENT POLICIES

Different policy instruments are available to support ocean energy. As of year-end 2017, 7 countries (UK, The Netherlands, Denmark, France, Italy, Canada and Japan) have adopted feed-in policies (FIT) making this the most widely adopted regulatory mechanism to promote ocean energy in the OES member countries (see Table 3). Ireland is the most recent country in the process of approving a FIT programme. In UK, the support scheme for wave and tidal energy is based on "Contracts for Difference (CfD)" auctions introduced in 2014 replacing the Renewable Obligations system in the UK. Portugal abolished its FIT policy in 2017.

Tradable green certificates are used in four countries (Belgium, Norway, Sweden and Korea). In Korea, the Tradable Renewable Energy Certificates (REC) supplement the Renewable Portfolio Standards (RPS) policy.
The United States relies particularly on tax incentives to support renewables like the Federal Production Tax Credit (PTC) and the Business Energy Investment Tax Credit (ITC) in general.

Of the 24 member countries, 7 do not have any specific market deployment incentives for ocean energy.

Roadmaps for the development of ocean energy have been articulated in a number of countries, providing long-term frameworks for developing policies and supporting actions. Some of these roadmaps are technology focused providing a guide for mobilising national efforts down a deployment pathway towards a target. These roadmaps can provide focused and coherent approaches to technology development in the ocean energy sector and their successful implementation depends upon a number of complex interactions between commercial, political and technical aspects.

OTHER POLICIES IMPACTING ON OCEAN ENERGY

The progress of ocean energy projects in all the OES member countries continues to face challenges in relation to consenting processes. There is a consensus that it is necessary to streamline and accelerate the consenting processes by removing excessive administrative and cost burdens.

Governing ocean energy as a specific sector is rare. Rather ocean energy tends to be administered through existing legal instruments for marine development or for renewable energy in general. Regulatory and administrative policies and frameworks, such as consenting, environmental impact and planning procedures, can simplify the process of deploying technology by clearly instructing developers on how to secure consent for a project.

Some policies have been implemented to reduce administrative barriers such as: i) **One-stop-shop approach**, e.g. one responsible authorisation agency acting as a single point of contact for dealing with consents. Ii) **Marine Spatial Planning (MSP)** in order to coordinate decisions on the uses of marine resources, iii) **Guidance and advice on consenting** of ocean energy device deployments and iv) **Ocean testing facilities** at different scales, providing grid infrastructure and equipment to measure the resource.

TABLE 1: NATIONAL STRATEGIES FOR OCEAN ENERGY DEVELOPMENT AND MARKET INCENTIVES

	NATIONAL STRATEGY				MARKET INCENTIVES					
	Capacity Targets	National Strategy or Action Plan	Technology Roadmap	Marine Spatial Plan	Feed-in Tariffs	Contracts for Difference (cfDs)	Green Certificates	Quota obligations or RPS	Renewable Energy Auctions	Tax Credit
Belgium			x	x			x			
Canada	x	x	x	x	x					
China	x	x		x			x			
Denmark			x							
France	x			UD	x					
Germany				x	x					
India										
Ireland	x	x	x	UD	UD					
Italy	x				x					
Japan		x	x		x					
Korea	x	x	x					x		
Mexico	x		x				x			
Netherlands				x	x					
Monaco				x						
Norway				x			x			
New Zealand				x						
Portugal	x	x	x	x						
Singapore										
South Africa				x						
Spain	x								x	
Sweden		x		UD			x			
United Kingdom	x	x	x	x		x				
USA		x		x						

UD: Under development

COUNTRY HIGHLIGHTS IN 2017

BELGIUM

- Laminaria has raised €2 million to support the development of its wave energy technology and to start a full scale demonstration project at the European Marine Energy Centre (EMEC) in Orkney, Scotland (LAMWEC project).
- The construction of the Belgium Marine Energy Centre, including a new coastal and offshore basin, where small to medium scale test devices can be tested, begun in 2017.

CANADA

- Activity in wave, tidal, and river current energy made important strides across Canada in 2017, positioning the sector to provide a clean electricity solution that can contribute to a low-carbon economy for Canada and globally.
- A number of policies and programmes at the federal and provincial levels focused on climate change and clean growth were established in 2017.
- Several small scale technologies and projects were successful deployed. Notably, most of these projects were focused on remote and Indigenous community applications to displace the use of diesel fuel.
- Cape Sharp Tidal's turbine was successfully recovered from the Fundy Ocean Research Center for Energy (FORCE) site in Nova Scotia. Ongoing environmental monitoring by FORCE and Cape Sharp Tidal are assisting to better understand the natural environment and the potential effects of turbines.
- The Canadian marine renewable energy sector continued to conduct important R&D and innovation activities through FORCE, the West Coast Wave Initiative (WCWI), Canadian Hydrokinetic Turbine Test Center (CHTTC), and Wave Environment Research Center (WERC).

CHINA

- In 2017 the Chinese Government supported marine renewable energy projects with a total budget of RMB 137 million granted to 4 marine energy projects. Since 2010 China has committed to date approximately about RMB 1.25 billion to marine energy RD&D.
- In February 2017 the Government released the "Regulations for the Trial Implementation of Renewable Energy Green Power Certificate" (REGPC).
- A new offshore floating cage with a wave power supply system conducted by the Youlian shipyard and the Guangzhou Institute of Energy Conversion, has been investigated; other types of supply schemes powered by OTEC and salinity gradient have also been studied.
- China has been investing in new test sites: a test site in Weihai, Shandong, a tidal current test site in Zhoushan, Zhejiang developed by the China Three Gorges Corporation and a wave energy test site in Wanshan, Guangdong.
- The Sharp Eagle wave energy demonstration project (100 kW) has been upgraded for application on remote islands and was tested from March to December 2017.
- The LHD tidal current energy demonstration project has now 2 turbines installed and connected to the grid; a new 300 kW horizontal-axis turbine is being developed by LHD and Blue Shark Power System, planned to be installed in July 2018.
- Zhairuoshan Tidal Stream Energy Power Demonstration Station has been operational since 2015 with a 120 kW turbine and it will soon accommodate a new 600 kW turbine. Other projects are being developed and planned to be tested in this station.

DENMARK

- During the autumn of 2017 the Danish partnership presented a strategy for wave energy to the Danish Parliament.
- Grid connection at the DanWEC test site is under consideration.
- Floating Power Plant has successfully tested a grid connected ½ scale prototype over 2 years and is currently developing 3 commercial projects with DP Energy in Scotland, Wales and Ireland.
- Other active developers in Denmark are Resen Waves, Weptos, Wavepiston, Crestwing, Wave Dragon and Exowave which have done progresses during the year.

EUROPEAN COMMISSION

- In 2017, a Temporary Working Group for Ocean Energy set up an implementation plan with concrete R&I activities, and funding opportunities. The group is composed by 10 Member States and relevant industrial partners, chaired by national representatives from Ireland and co-chaired by the European Technology & Innovation Platform on Ocean Energy (ETIP Ocean). The Implementation plan is expected to be endorsed in 2018.
- A stable ocean energy sector is expected to contribute significantly to the growth of EU maritime regions, with estimates suggesting that the ocean energy sector could generate over 400,000 jobs by 2050 if the

industrial target to deploy 100 GW of installed capacity is met.

- A study is currently underway to address the long-term failures of the ocean energy market with the aim to identifying mechanisms to support market formation and mobilise investment into the sector.
- A tender has been launched addressing the monitoring of wave and tidal energy devices in order to remove uncertainties over their potential environmental impacts.
- Under Horizon 2020 more than €124 million for ocean energy R&D to 24 different projects have been granted since 2010.
- There are several funded projects supporting open sea testing: MaRINET 2 and Foresea offer developers access to testing infrastructures; Marinerg-I is developing a vision to an integrated European Research Infrastructure for the development of ocean energy technologies; Met-Certified looks to the development of standards and certification schemes for ocean energy technologies.
- Fourteen EU Projects on ocean energy are currently funded, five of which were awarded in 2017. Five pre-commercial projects are ongoing with support through NER300.
- In 2017, Atlantis Resources Limited started the due-diligence process to obtain support through the InnovFIn EDP scheme, from the European Investment Bank (EIB) together with the European Commission.

FRANCE

- A new law to simplify the deployment of marine renewable energies is under discussion; following the Marine Spatial Planning (MSP) consultation launched in 2016, dedicated sites for ocean energy projects are now being identified.
- The tidal sector is expecting a call for tenders at a commercial scale with two high-energy zones having already been identified: Raz Blanchard and the Fromveur Strait in Brittany.
- In 2017, 6 R&D projects awarded national funding. These public-private collaborative projects tackle technological bottlenecks and environmental issues on marine renewable energies.
- Two French Sea Clusters - Pôle Mer Bretagne-Atlantique and Pôle Mer Méditerranée – have marine energies in their roadmaps.
- Much activity is going on at the French open sea test sites (SEM-REV, SENNEOH, Paimpol Bréhat and Brest Saint-Anne).
- EEL Energy is developing an undulating membrane inspired by biomimicry (fish swimming) to generate electricity from marine or river currents, which has recently been tested at Brest Harbour.
- Sabella is planning to continue its demonstration installation on Ushant, an island at the western end of Britanny, within the scope of the ICE project (2017 – 2020), "Intelligent Community Energy".
- Naval Energies launched, in July 2017, the construction of a facility in Cherbourg dedicated to the assembly of 25 turbines/year for the development of the Normandie Hydro tidal turbine pilot farm project.
- Guinard Energies proceeded to several operational tests at sea in Brest (Brittany) in 2017, with a 3.5 kW hydrokinetic device combined with solar panels and batteries.

GERMANY

- In 2017, the Government introduced a market-based auction scheme for renewables; however for hydro power plants (including ocean energy) fixed Feed-in Tariffs continue to be applied.
- Up to now, around 12 technology projects related to the development of components and concepts for tidal turbines and wave energy components have been funded by the Government. The new funding programme is expected to be released in the summer of 2018.
- SCHOTTEL HYDRO decided to discontinue their "TRITON" platform and are now moving to smaller floating platforms. The company is however continuing to provide their "SIT" tidal turbines and custom power take-off systems to third party tidal developers like SME, QED Naval and Minesto.
- NEMOS with other German partners is continuing the development of its wave energy conversion technology. The construction of the full scale prototype started in February at a Belgian shipyard and the installation in the North Sea near the Port of Ostend was permitted in June 2017.
- SINN Power started a project in August 2017 that will run until July 2019 and is supposed to deliver four additional wave energy converters to the existing test site in Greece. They also have plans for an installation at an organic shrimp farm in Cape Verde.
- REAC Energy tested a single unit of their modular tidal turbine "StreamCube" in Orkney waters in October 2017.
- The project STENSEA – "Stored Energy in the Sea" was tested in Lake Constance, Germany, and is currently being developed at larger scale.

INDIA

- In 2017, NIOT organised a brainstorming session on Ocean Energy Development in India with key stakeholders from industry, academia and public sector.
- India hosted the 33rd meeting of the OES in November 2017 in Chennai and organised a workshop on ocean energy development with the presence of participants from Department of Science and Technology, Ministry of New and Renewable Energy, Indian Institute of Technology, Ministry of Earth Sciences.
- Also two important ocean energy technologies were inaugurated in 2017: a wave powered navigational buoy off Chennai coast which will be used to mark navigational channels in ports and harbours, and a laboratory for carrying out studies on various components of OTEC and Low Temperature Thermal Desalination (LTTD).
- NIOT is building a few more wave powered navigational buoys to be deployed at different ports on the east coast of India and exploring sites for tidal current turbines.
- Preparatory work for the OTEC powered desalination plant in Kavaratti in the Union Territory of Lakshadweep is almost completed.

IRELAND

- In 2017, the Offshore Renewable Energy Development Plan, prepared 3 years ago, was reviewed by relevant stakeholders at government and industry level to ensure continued focus on appropriate priority areas.
- A public consultation focused on the design options of the new Renewable Electricity Support Scheme in Ireland was held in September 2017 and feedback is expected during 2018.
- Significant steps were taken in 2017 to further develop Irish testing facilities. At the Atlantic Marine Energy Test Site (AMETS), a foreshore lease has been awarded for the site, planning permission for onshore aspects have also been secured and grid connection work has commenced.
- GKinetic carried out tests on an improved prototype at the Limerick docks.
- SeaPower tested a prototype at Galway Bay test site from November 2016 until March 2017.
- OE Buoy is progressing to test a half scale model in US Navy WETS facility in Hawaii in late 2018 and Westwave project is ongoing to securing the required permits and conducting site investigations in the Irish coast.

ITALY

- In 2017, the Government launched two calls for proposals to grant funding for strategic research activities, including the Blue Energy sector.
- There is an increasing interest in the exploitation of wave and tidal energy converters in the country and a number of new developments are progressing. ENEA continues carrying out an intense coordination activity aimed at bringing together the major Italian actors in the ocean energy sector.
- The first full scale prototype of REWEC3, an OWC integrated in a breakwater developed by the Università Mediterranea di Reggio Calabria is under construction in the port of Civitavecchia (Rome, Italy) with a total length of 578 m. Total installed power will be 2.5 MW.
- Another breakwater based on the wave overtopping system has been developed by Università degli studi della Campania in the port of Naples since 2015, and its performance is continuously being monitored.
- Politecnico di Torino has been developing two wave energy devices: ISWEC, based on gyroscopic technology, tested offshore the coast of Pantelleria since 2016 and PEWEC in collaboration with ENEA.
- A first full scale prototype of the ocean current energy system, known as GEM or Ocean's Kite, was deployed in Venice lagoon.
- KOBOLD turbine built by the Ponte di Archimede and installed in 2000 in the Strait of Messina is still in operation and grid connected.

REPUBLIC OF KOREA

- The Korean Government has a new Plan for Ocean Energy for 2030 which includes the construction of 1.5 GW ocean energy infrastructures and promotion of new industries in this sector.
- Since 2000, the Government has invested a total of USD 200 million for ocean energy technology development projects.
- Wave energy technology in breakwaters, on remote islands, remains a topic of intensive research in Korea.
- The 500 kW Yongsoo OWC pilot plant offshore Jeju Island completed in July 2016 is now planned to be utilized as an offshore substation for open sea testing. The 300 kW Floating Pendulum Wave Energy Converter developed by KRISO is expected to be tested there in 2018.
- A test site for tidal energy converters with 4.5 MW grid connected capacity is being carried out, planned to be installed at the southwestern waters of Korean peninsula, close to the Uldolmok tidal current pilot plant.
- An active-controlled, high efficiency and low cost 200 kW Tidal Energy Converter (TEC) developed by

Korea Institute of Ocean Science and Technology (KIOST) will be installed in the Uldolmok test site for open sea test in early 2018.
- The 20 KW OTEC and 200 KW HOTEC plants have been in operation; performance tests are being conducted by a subsidiary research centre of KRISO dedicated to deep sea water applications.
- For the commercialization phase of OTEC, KRISO is developing a 1 MW OTEC demonstration plant, which is expected to be tested in 2018 at the east coast of South Korea and then transferred to Tarawa, Kiribati, in 2019. The Environment Impact Assessment (EIA) has already been done.

MEXICO

- To strengthen the operation of the Mexican Energy Innovation Centres (CEMIEs), the Ministry of Energy developed Technological Roadmaps (TRM) for different renewable energies, including ocean energy.
- Mexico estimates that ocean energy can contribute with 500 to 1000 MW of installed electrical capacity by 2030.
- CEMIE-Oceano is developing two wave energy projects to be installed at the sea, in Sauzal Port, Baja California and at Lazaro Cardenas, Michoacan. Further, an OTEC facility for installation in Acapulco, Guerrero, is being investigated.

MONACO

- On the instigation of H.S.H. Prince Albert II, the environment and subjects related to sustainable development are among the most important political priorities in the State of Monaco, on both a national and international level. Their Climate and Energy Plan includes technical, regulatory, financial and awareness-raising campaigns.
- A dedicated funding instrument has been created for innovative projects.
- Ocean energy activities in Monaco are related with the demonstration of sea water heat pumps to generate energy: 80 sea water heat pumps produce 20% of the energy consumed in the Principality (about 191 GWh/year). Many buildings located on the coast benefit from this reversible system, for heating in winter and air-conditioning in summer.

THE NETHERLANDS

- Several institutions joined forces in a trade association called the EWA (Netherlands Energy from Water Agency).
- A generic national existing subsidy scheme (SDE) has been opened for tidal current, wave energy and free flow energy.
- SeaQurrent started the developed of their tidal kite in 2017.
- EDstack, a salinity plant on Afsluitdijk signed a contract with four partners for scaling up to a 1 MW demo pilot plant.
- Bluerise has made significant progress and signed a Joint Venture agreement for the construction of a 21 MW thermal Deep Seawater District Cooling system in Jamaica and is further progressing with Curaçao project consisting of the development and operation of a 10 MW thermal Deep Seawater District Cooling system, combined with 500 kW OTEC power generation.

NEW ZEALAND

- The NZ Government has a long-running commitment to a goal of 90% renewable electricity supply by 2025, with an additional target of 100% renewable electricity supply by 2035 being introduced in late 2017.
- The US-based company NWEI, in partnership with NZ-based Energy Hydraulics (EHL), and others, concluded testing of the Azura Wave device at the US Navy's Wave Energy Test Site at the Marine Corps Base Hawaii. This project is a continuation and evolution of the initial technology development in New Zealand known as WET-NZ.

NORWAY

- The Norwegian Energy Agency, Enova, offers capital grants for full scale ocean energy demonstration projects. Further, Innovation Norway has been running a programme supporting prototypes within "Environmental friendly technology", including ocean energy.
- In Norway, a grid connected wave energy buoy, Wave-EL, from the Swedish company Waves4Power, was launched in June 2017, at the Runde Environmental Centre (REC).
- There are a number of other planned deployments, from 3 active Norwegian companies, Tidetec, Havkraft and Deep River.

PORTUGAL

- In 2017, the Portuguese Government approved the Industrial Strategy for Oceanic Renewable Energies (EI-ERO) with a set of measures for wave energy and floating offshore wind.
- Under the new funding mechanism "Fundo Azul" (Blue Fund) to develop the ocean economy, tenders were opened during 2017 for ocean energy projects.
- The Institute of Mechanical Engineering (IDMEC) at IST has been concentrated on the development of new types of oscillating water column (OWCs) converters and self-rectifying air turbines.
- IDMEC/IST, jointly with the Portuguese company Ky-

maner, designed a prototype of a biradial self-rectifying air turbine with a new type of fixed guide vanes and a fast valve under the EU project OPERA led by Tecnalia. The turbine was installed at one of the OWCs of the Mutriku breakwater (Basque Country, Northern Spain) and has been tested since June 2017.

- In 2017 AW-Energy continued to work with Portuguese authorities to license the FOAK project and also their first wave energy park in Peniche - the project called "Ondas de Peniche" winner of the NER 300.
- The UK-based tidal energy developer Oceanflow Energy has been testing their Evopod E1 in the South of Portugal, at Ria Formosa, within a EU funded project SCORE, running since 2016.
- Pico power plant in Azores was still operational and grid connected during 2017.

SINGAPORE

- In 2017, the Singapore Economic Development Board (EDB) has secured investments from six clean energy companies worth $500 million for next five years.
- The Sentosa Tidal Test Site aims to showcase tidal energy extraction as a feasible and sustainable energy generating technology in the country and to provide opportunities to develop local technologies. Recent developments on this test site include the deployments of tidal turbines on floating barges.
- The Energy Research Institute at Nanyang Technological University (ERI@N) has been working with international partners in developing and test bedding tidal in-stream energy systems for island conditions with micro grids architecture, such the project at Bintuni Bay, West Papua, Indonesia, with Schottel Hydro.
- Pulau Semakau, an island south of mainland Singapore, has been used for the development of energy technologies suited for tropical conditions, under the REIDS project. 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.

SPAIN

- The so-called MARMOK-A-5 device, developed by OCEANTEC celebrated 1 year of trials, connected to the grid at BIMEP, with 1000 hours of operation. The prototype development received funding from the Basque Energy Agency and is part of the OPERA project funded by the European Commission.
- The Mutriku wave power plant at the Basque Country in the North of Spain has completed six years of continuous operation reaching a record of cumulative energy from waves powered to the grid of almost 1.5 GWh.
- At Plocan, two submarine cables (5 MW/13,2 kV) started to be installed in 2017 expected to be fully commissioned during the first semester of 2018.
- A wave-pumped desalination project is expected to be installed in 2018 at PLOCAN, promoted by the company Tveter Power.
- Several test campaigns were carried out at BiMEP in 2017 including the oceanographic buoy ANTEIA, developed by the company ZUNIBAL, and the 6 months survivability trials of the electric subsea connector Konekta2 conducted by DITREL.
- Wedge Global has been testing a prototype on Canary Islands, accumulating roughly 4 years, continuously in the Atlantic Ocean. The company is also developing SMARTWEC Project funded by SODERCAN (Cantabria Regional Government) aiming to analyse the technical-economic viability of a wave energy farm off the Cantabrian coast.
- Magallanes Renovables finished its 2 MW floating platform in April 2017 and has started its mooring and towing tests before the installation at EMEC after the winter period.

SWEDEN

- Since 2015, the Swedish Energy Agency has been running a national ocean energy programme with a total budget of around €5,7 million for 4 years. The programme is now being evaluated in parallel with the planning of a new programme stage.
- At the Lysekil wave energy research test site at the west coast of Sweden a signal cable and a 230 V cable was installed during 2017. A Seabased wave power plant was connected to the land cable in June.
- The Sotenäs Project initiated in November 2011 has until now deployed 36 wave energy generators.
- The Swedish company Waves4Power has been demonstrating a full scale wave power device at sea, at Runde Test site in Norway. On 2 June 2017, the device was connected to the grid and started delivering electricity. Due to damage of two of the mooring lines Waves4Power chose to tow the buoy to Fiskåholmen in late November 2017 for a detailed analysis of the mooring system.
- There are a few deployments from Swedish companies planned in the near future but taking place outside Sweden: Minesto has been tested in Strangford Lough, Northern Ireland since 2011; CorPower Ocean did dry tests in Stockholm during 2017 prior to their installation at EMEC.

UNITED KINGDOM

- Wave Energy Scotland (WES), a Scottish Government funded technology development programme, has so far awarded £24.4 million to 61 technology development projects in the areas of power take-offs (PTOs), novel devices, structural materials and manufacturing processes and control systems.
- Marine Energy Wales, a Welsh Government supported initiative, granted funding to the Anglesey Tidal Demonstration Zone for the project consenting.
- In 2017, the decision was made to amalgamate the Wind Power and Marine Energy Supergen hubs into a new Offshore Renewable Energy (ORE) hub, as the two sectors were identified as having sufficient synergies.
- The UK's tidal stream sector made significant progress towards commercialisation in 2017, with a number of turbine deployments including two at array scale.
- The MeyGen project in Scotland's Pentland Firth operated by Atlantis Resources has completed construction of Phase 1A of the project, with four turbines and a capacity of 6 MW. In August 2017, 1,000 MWh of electricity was generated by the MeyGen array.
- Nova Innovation deployed the third 100 kW turbine of the Shetland Tidal Array in early 2017 and signed a lease for a 2 MW project at Bardsey Sound in North Wales.
- Scotrenewables Tidal Power commissioned their first full commercial scale machine, the SR1-2000 2 MW at EMEC. The SR1-2000 was fully grid connected over the testing period and generated over 1.3 GWh.
- EMEC host six developers in 2017: UK-based EC-OG, Nautricity and Scotrenewables Tidal Power, Ireland-based OpenHydro, Netherlands-based Tocardo and Finnish wave developer Wello.
- The FORESEA and MaRINET2 calls in 2017 instigated a resurgence of wave and tidal developers planning test and demonstration projects at EMEC in the course of 2018.
- DP Energy continue to progress through planning and consenting processes with a view to install a tidal stream array at Fairhead in Northern Ireland of 100 MW capacity.
- Open Hydro have a 200 MW application submitted and being considered for a tidal development on the north side of the Pentland Firth.

THE UNITED STATES

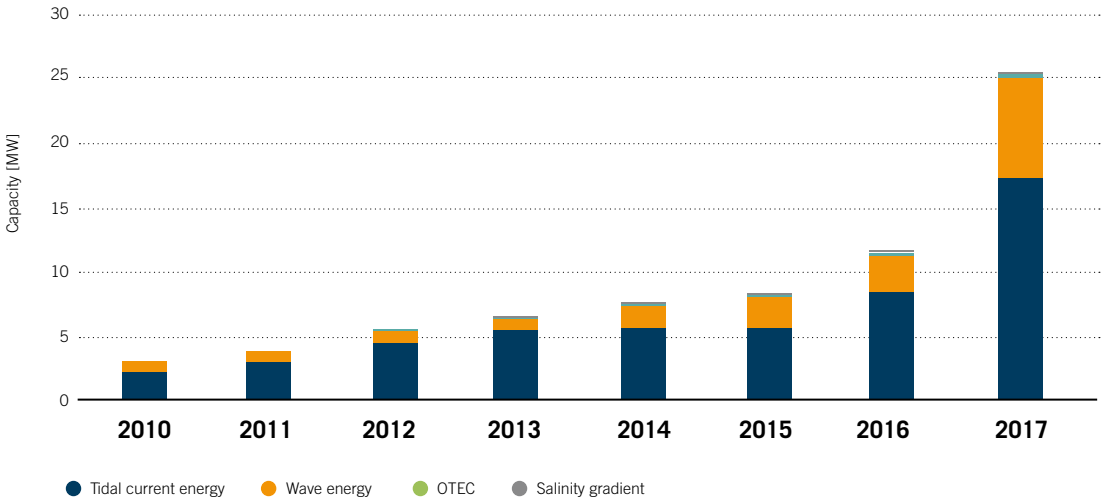
- The U.S. Department of Energy (DOE) Water Power Technologies Office has been refining their draft National Strategy for Marine and Hydrokinetics, recognising the challenges related with the development of commercial marine renewable energy technologies and proposing 4 approaches to address each of the challenges along with associated categories of activities which the DOE intends to support over time.
- Federal funding has maintained an upward trend since 2013. The FY 2017 annual budget was funded from the water programme at $59 million—a 33% increase from previous year.
- ABB along with partners at Texas A&M's Advanced Electrical Machines Lab and Resolute Marine Energy developed and tested an integrated magnetic gear generator.
- NREL completed deployment of two buoys with high accuracy sensors to record wave and tide movement off the coasts of Oregon and Maine.
- Ocean Renewable Power Company completed full scale testing of a specialized bearing system and associated driveline components.
- SNL, in conjunction with the U.S. Navy, tested advanced controls on a WEC at the Navy's Maneuvering and Seakeeping (MASK) Basin in Bethesda, Maryland.
- NNMREC conducted several laboratory experiments with cross-flow turbines and simulations of wave energy converters.
- Fred Olsen, with its BOLT Lifesaver, completed a one-year demonstration project at the Navy's WETS in Hawaii in April 2017.
- A number of other projects have plans for deployment at the Wave Energy Test Site in Hawaii: The OE Buoy is slotted for half scale device testing in the latter half of 2018; Columbia Power Technologies is planning to test a 1/3 scale system of their StingRAY wave energy converter device. Northwest Energy Innovations is currently developing a full scale Azura™ to be tested at this test site.
- Verdant Power plans to test their project in the East River near New York City.
- There are twelve open water test sites in USA that are operational and one under development. These sites can accommodate scaled prototypes to full scale grid connected devices.

INSTALLED CAPACITY

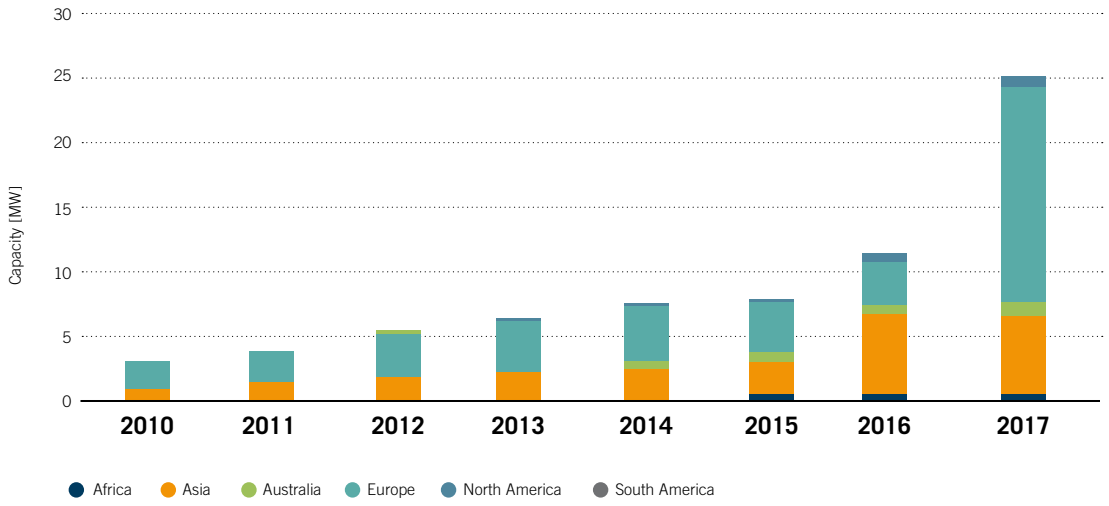
In 2017, global installed ocean energy power has approximately doubled compared with previous year.

Tidal current deployments have increased to over 17 MW in 2017. The major projects behind this development are MeyGen/Inner Sound Phase 1A in the UK, Paimpol-Bréhat in France and the LHD Tidal Current Energy Demonstration Project in China. Wave energy deployments has also doubled to 8 MW in 2017. The main drivers of this development are the Sotenäs project in Sweden and Wello's Penguin prototype at the European Marine Energy Centre (EMEC). However, some of these wave and tidal current projects suffered removals and redeployments. OTEC and Salinity Gradient have a minor share of the global installed ocean energy capacity so far. These deployments have mainly occurred in Europe and in second place in Asia.

In what concerns tidal range utilisation (not represented in the pictures below), around 522 MW of operational plants exist in Europe, Asia and North America, the most recent being the Sihwa Tidal Power Plant in the Republic of Korea, with rated power of 254 MW, operational since 2011.



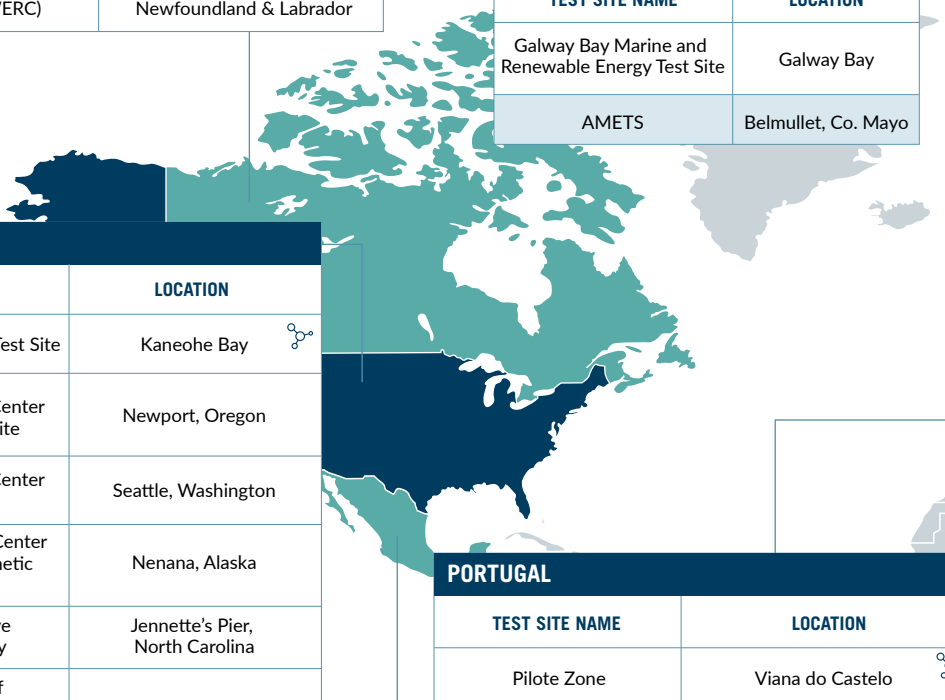
Cumulated ocean energy capacity by energy source in the period 2010 – 2017 (tidal barrage not included)
Source: OES WebGis Database - Fraunhofer IEE



Cumulated ocean energy capacity by location in the period 2010 – 2017 (tidal barrage not included)
Source: OES WebGis Database - Fraunhofer IEE

OPEN SEA TEST SITES

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

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

UNITED KINGDOM

TEST SITE NAME	LOCATION
EMEC	Orkney, Scotland
Wave Hub	Cornwall, England

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 North Energy Test 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
Pacific Marine Energy Center South Energy Test Site	Newport, Oregon

PORTUGAL

TEST SITE NAME	LOCATION
Pilote Zone	Viana do Castelo

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

Operational

Under Development

Grid connected

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
K-WETEC (Korea Wave Energy Test and Evaluation Centre)	Jeju
Tidal Energy Open Sea Test Centre	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

01.
OVERVIEW OF OES

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

The OES embrace the full range of ocean energy technologies:

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

Offshore wind, marine biomass or submarine geothermal which occupy sea space but do not directly utilize the properties of seawater, are not included in the OES remit.
Most ocean energy technologies are being developed to produce electricity, although some of them are being developed to deliver other or multiple products, derived from the physical and chemical properties of seawater (e.g. fresh water and sea water air conditioning).

VISION, ROLE AND VALUES

VISION

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

ROLE

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

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

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

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

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

ORGANISATION VALUES

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

Integrity: Any information provided can be relied upon.

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

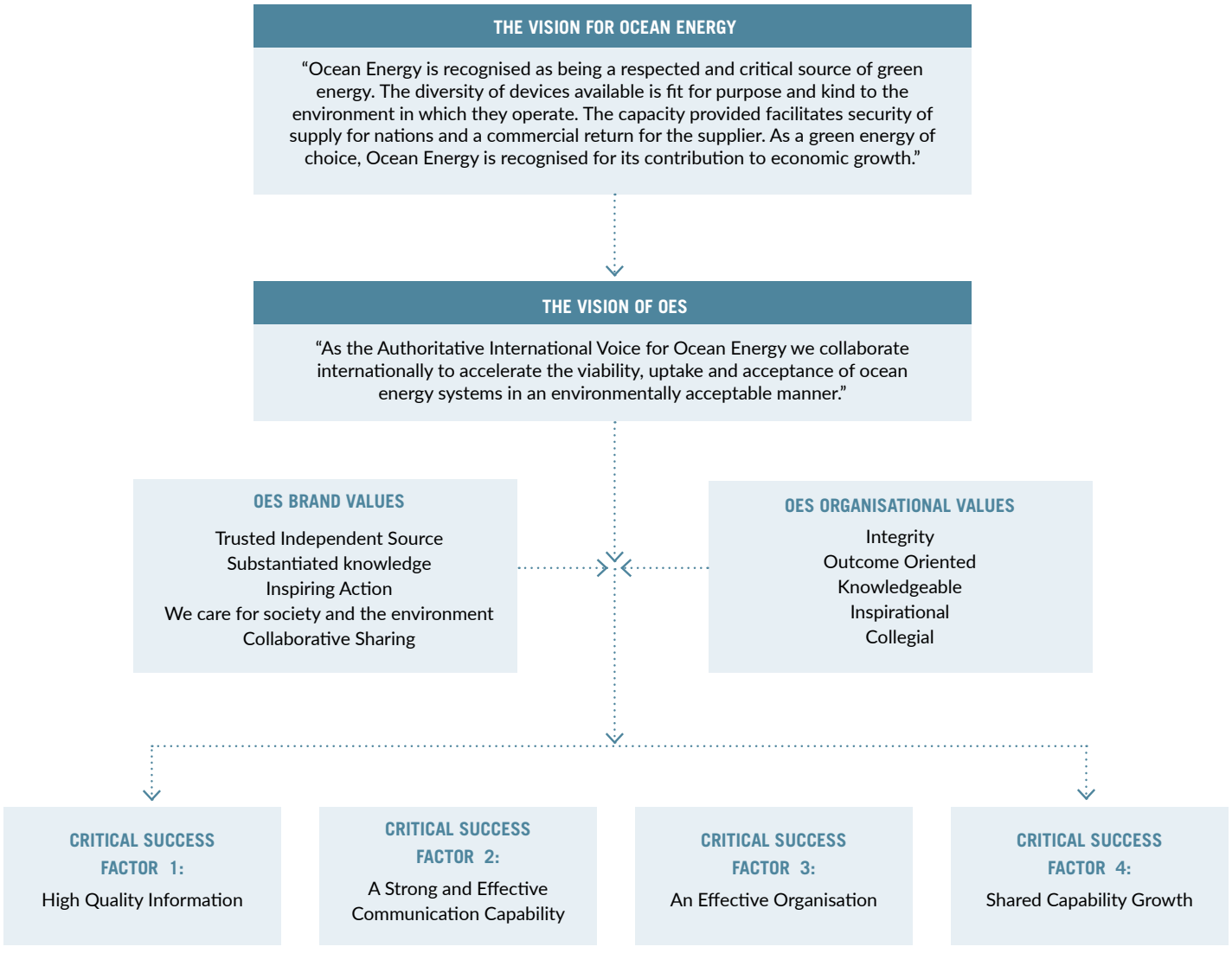
Knowledgeable: All information is based on fact and we strive to ensure that we always have the most relevant and up-to-date researched facts available.

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

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

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

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



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 2017, 24 Member Countries and the European Commission are members of the OES (Fig.1).

National governments appoint a Contracting Party to represent the country in the Executive Committee (ExCo) (Table 2). 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 (Fig. 2). The ExCo considers this diversity to be a key strength of the organization and will strive to maintain this balance of representation.

Communication continues with the governments of the following countries: Australia, Argentina, Brazil, Chile, Colombia, Finland, Ghana, Greece, Indonesia, Malaysia, Malta, Mauritius, Peru, Philippines, Russia and Uruguay. The ExCo has adopted a practice of encouraging potential member countries to send observers to ExCo meetings. Observers are invited to attend up to three meetings, after which it is expected that the country will commit to joining the ExCo. This has proven an effective way of encouraging membership.

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.

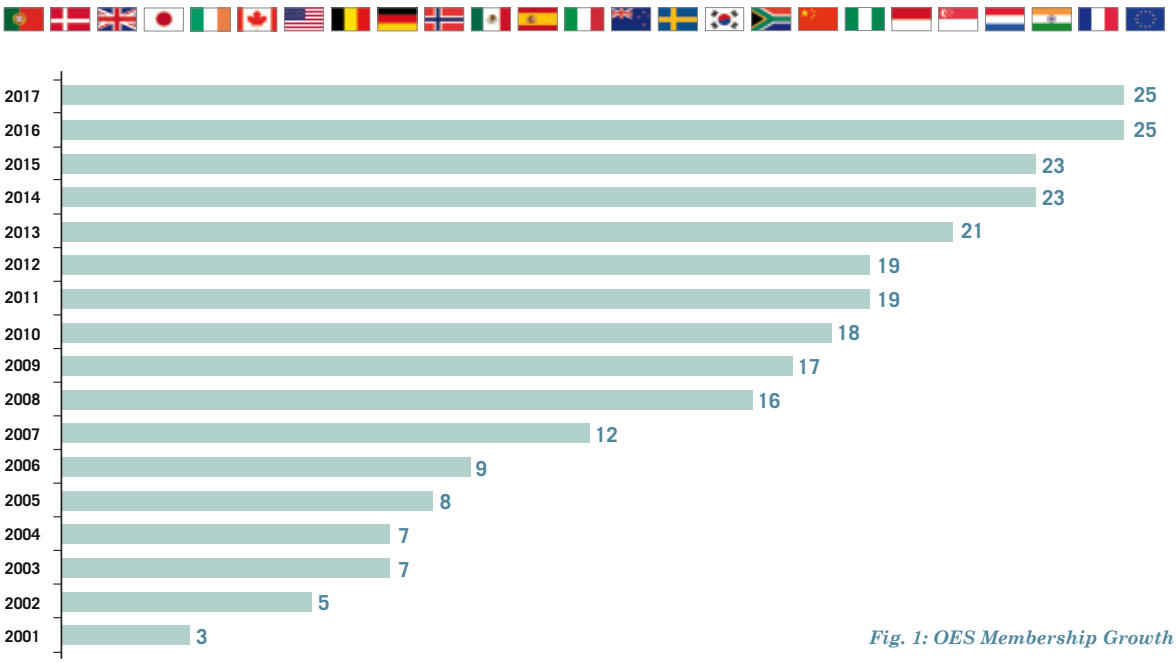


Fig. 1: OES Membership Growth

TABLE 2: CONTRACTING PARTIES (END DECEMBER 2017)

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	TECNALIA
	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	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

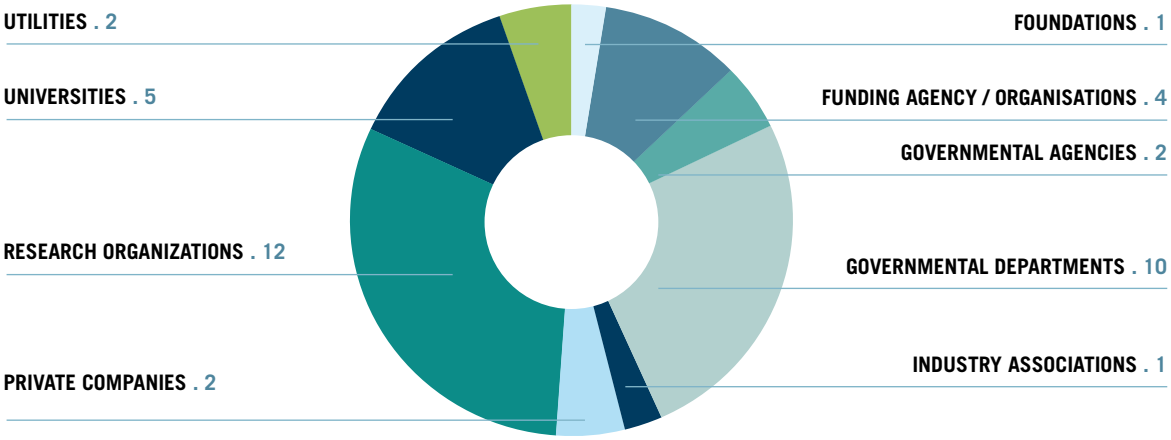


Fig. 2: Diversified representation of interests in the ExCo

EXECUTIVE COMMITTEE

The overall programme is headed by an Executive Committee (ExCo) composed of representatives from each participating country and organisation. The ExCo meets twice a year and takes decisions on the management, participation and implementation aspects of the OES.

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 32nd ExCo meeting took place in the Principality of Monaco, on 10 – 11 April with 20 Delegates and 2 Observers (Chile and Australia). On the occasion of this event headed by the Monegasque National Committee of the World Energy Council, in partnership with the Government and the Prince Albert II of Monaco Foundation, the Chairman of the OES, presented the Ocean Energy Systems 2016 Annual Report to the HSH Prince Albert II of Monaco.

On 11-13 April, Monaco organized once again their international event, Renewable Energies & Ecologic Vehicles Forum & International Conference, in the Grimaldi Forum, Monte Carlo. At EVER2017, a roundtable on marine energies has been organized with the participation of OES delegates from UK, USA, China, Spain and France.

Fig. 3 - 32nd ExCo Meeting in Monaco (10-11 April 2017)

Fig. 4 - 33rd ExCo Meeting in Chennai, India (14 - 15 November 2017)

The 33rd ExCo meeting was held in Chennai, India on 14-15 November and there were 16 Delegates and 1 Observer (Indonesia).

In Chennai, OES delegates participated as well in the workshop *'Harnessing Energy from the Oceans - A Global Scenario'* organized by the National Institute of Ocean Technology (NIOT), on the 13th November, with the presence of the Secretary of the Ministry of Earth Sciences and the Director of NIOT. During this workshop an inaugural session of the Indian wave powered navigational buoy and OTEC facility were organised.

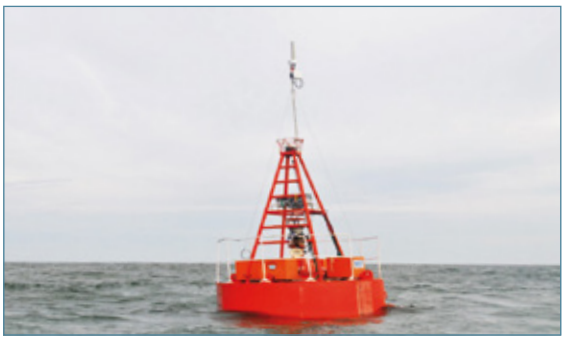
The ExCo elects a Chairman and two Vice-Chairs, who serve for a 2-year term. Together with the Secretary, the Chairman and Vice-Chairs form the Cabinet, which manages the day-to-day decision-making to implement the annual Work Programme. The ExCo Secretariat is based in Lisbon, Portugal and is run by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

In 2017, Henry Jeffrey (United Kingdom) served as Chair and Jose Luis Villate (Spain) served as Vice-chair until the second ExCo meeting (ExCo 33) in November 2017. At ExCo 33, Annie Dallman (USA) and Yann-Hervé De Roeck (France) were elected as Vice-chairs.

A list of the members of the ExCo during 2017 is shown in Appendix 1.

In 2017, OES participated in the 72th IEA Renewable Energy Working Party Meeting (REWP 72) held in Lisbon, Portugal, on 10-12 October 2017.

OTEC Desalination Laboratory inaugurated on the 13th November 2017



NIOT wave powered buoy inaugurated on the 13th November 2017

WORK PROGRAMME

The OES is self-financed by the participants, either through financial and/or in-kind contributions. The participants themselves decide whether cost-sharing, task-sharing or a combination of both is most appropriate. Under the cost-sharing approach, each participant contributes to a common fund which can then be used to finance activities under the OES's programme of work; under the task-sharing approach, each participant contributes resources in-kind. In 2017, OES had 10 active co-operative tasks bringing together experts from industry, government, and research institutions around the world to exchange information and participate in various research activities (Table 3).

Two tasks were approved in 2017 by the Executive Committee: Task 12 on Stage Gate Metrics for Ocean Energy and Task 13 on Numerical Code Validation for Tidal Energy, both of which will formally begin in 2018. The ExCo also approved a new study on the Cost of Energy, as a continuation of the work done in 2016 under task 7.

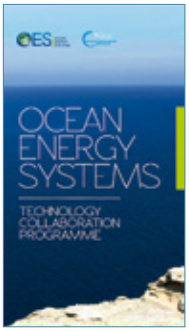
Further, three proposals for new activities were discussed in the last ExCo meeting addressing ocean energy in insular conditions, ocean energy jobs creation and open water testing. These proposals are presented in chapter 2.

TABLE 3: OES WORK PROGRAMME

TASK Nº	TITLE	LEAD BY	STATUS
Task 1	Review, Exchange and Dissemination of Information on Ocean Energy Systems	Portugal	Active
Task 2	Development of Recommended Practices for Testing and Evaluating Ocean Energy Systems	Denmark	Concluded
Task 3	Integration of Ocean Energy Plants into Distribution and Transmission Electrical Grids	Canada	Concluded
Task 4	Assessment of Environmental Effects and Monitoring Efforts for Ocean Wave, Tidal and Current Energy Systems	United States	Active
Task 5	The Exchange and Assessment of Ocean Energy Device Project Information and Experience	United States	Concluded
Task 6	Worldwide Web GIS Database for Ocean Energy	Germany	Active
Task 7	Cost of Energy Assessment for Wave, Tidal, and OTEC at an International Level	UK	Active
Task 8	Consenting Processes for Ocean Energy on OES Member Countries	Portugal	Active
Task 9	International Ocean Energy Technology Roadmap	UK	Active
Task 10	Wave Energy Modelling Verification and Validation	Denmark	Active
Task 11	Investigation and Evaluation of OTEC Resource	Japan	Active
Task 12	Stage Gate Metrics International Framework for Ocean Energy	European Commission	Active
Task 13	Tidal Energy Modelling Verification and Validation	Singapore	Active

TASK 1
COLLECTION OF INFORMATION AND DISSEMINATION

Task 1 focus on development of quality information products and effective communication mechanisms in support of the OES strategy. It further aims to provide adequate and accurate information to policy makers and other stakeholders.



COMMUNICATION ACTIVITIES

Task 1 aims at communicating the OES main findings trough the most appropriate communication channels. In this respect the following main communication actions are conducted throughout the year:

- The **OES website** is the primary source of communicating the activities of OES, publications and general outputs of each tasks to a wider audience (www.ocean-energy-systems.org). It includes a restricted area for the ExCo delegates with information to be discussed in each ExCo meeting and repository of all presentations in meetings.
- In order to increase the OES programme's visibility, news are also promoted trough a **LinkedIn group** and a **twitter account.**
- A **video** about ocean energy for the general public is available on youtube channel.
- The **Annual Report** is the flagship document of the OES and a marker for industry development. It includes detailed information from country members. A subdomain was created in the website with an interactive online version: http://report2017.ocean-energy-systems.org/
- A Bulletin issued each semester, after each ExCo meeting presents most up to date information exchanged by the delegates: https://www.ocean-energy-systems.org/news-events/newsletter/

PRESENCE IN RELEVANT EVENTS

Dissemination of OES activities has been an ongoing process, through the presence of OES representatives several events related to ocean energy. Table 4 lists the main events in 2017, in which the OES was represented.

Ocean Energy Conference at the Marine Energy Week, March 2017, Spain - Presentation of the OES International Vision by the Spanish Delegate, Jose Luis Villate

TABLE 4: OES PARTICIPATION IN INTERNATIONAL EVENTS DURING 2017

EVENT	COUNTRY	DATE
Ocean Energy Conference at the Marine Energy Week	SPAIN Bilbao	27 – 31 March
EVER 2017 - Renewable Energies & Ecologic Vehicles Forum & International Conference	MONACO	11 – 13 April
Mexico International Renewable Energy Conference (MEXIREC)	MEXICO Mexico City	11 – 13 September
Marine Renewables Canada, 2017 Annual Conference	CANADA Ottawa	8 – 9 November
WOC Sustainable Ocean Summit 2017	CANADA Halifax	29 Nov - 01 Dec
Harnessing Energy from the Oceans - A Global Scenario	INDIA Chennai	13 November
International Workshop "Marine Energy for Europe's Overseas Countries and Territories" (organized by the European Commission)	BELGIUM Brussels	6 December

Mexico International Renewable Energy Conference, 11-13 September 2017 – Presentation of the OES International Vision by the Mexican Delegate, Rodolfo Silva-Casarín

CLOSE LINK WITH ICOE

The ExCo has had an intimate link with the **International Conference on Ocean Energy (ICOE)** series, since its inception in 2006. Although there are other regional ocean energy conferences, ICOE is the only truly global ocean energy conference. ICOE conferences are held every two years and focus on the industrial development of ocean energy. Past ICOE conferences have been held in Germany, France, Spain, Ireland, Canada and UK. In 2018, ICOE will be held in Cherbourg, Normandy, from june 12th to 14th in La Cité de la Mer (http://icoe2018normandy.eu/).

The International Steering Committee of ICOE includes the Chair of the OES. Further several OES delegates are also members of the steering committee.

In particular, the OES hosts past ICOE conference material on a dedicated website managed by OES (www.icoe-conference.com), providing the historical archive of all papers from previous ICOE conferences.

The OES is also the organiser and supporter of a "student poster award" - three cash prize for the best three poster presentation at the ICOE conferences. Active students and young early-stage researchers are eligible for the poster awards.

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. One example of supporting international collaboration work is the "International Collaborative Incentive Scholarships" (ICIS scheme), whereby pairs or groups of researchers from at least two different countries are awarded a small bursary to fund (usually travel) expenses that will allow a piece of work to be carried out at one of the group member's organisations.

COLLABORATION WITH IEC

International Electrotechnical Commission (IEC) Technical Committee (TC) 114, Marine Energy – Wave and Tidal Energy Converters: OES has a formal liaison with this technical committee to develop international standards for wave and tidal energy technologies. In 2017, Dr Purnima Jalihal, delegate from India on the OES Executive Committee has been nominated as the expert to coordinate, in particular, the collaboration with the working group "PT 62600-20 - General guidance for design and analysis of an Ocean Thermal Energy Conversion (OTEC) plant", on behalf of the OES. Further, a number of ExCo members serve as project leaders or participants in some of the TC114 working groups. Some OES tasks can provide technical information for future standards.

In 2017 the OES was invited to collaborate with the Marine Energy Operational Management Committee (ME-OMC) of the International Electrotechnical Commission Renewable Energy (IECRE) System (http://www.iecre.org) with a focus on test laboratories involved in marine energy. IECRE is conducting work for conformity assessment of marine energy, wind energy and solar energy. The OES accepted to have a formal liaison with this committee and Jose Luis Villate, Spanish alternate to the OES, was nominated the contact person for this liaison.

PUBLICATIONS IN 2017

- Huckerby, J., Jeffrey, H., de Andres, A. and Finlay, L., (2017). An International Vision for Ocean Energy. Version III. Published by the Ocean Energy Systems Technology Collaboration Programme; www.ocean-energy-systems.org
- Quirapas, M., & Srikanth, N. (2017). Ocean Energy in Insular Conditions - a Workshop Report prepared on behalf of the IEA Technology Collaboration Programme for Ocean Energy Systems (OES); www.ocean-energy-systems.org
- Wendt, Fabian, Yi-Hsiang Yu, Kim Nielsen, Kelley Ruehl, Tim Bunnik, Imanol Touzon, Bo Woo Namk, et al. "OES Task 10 WEC Modelling Verification and Validation" In Proceedings of the Twelfth European Wave and Tidal Energy Conference, edited by A. Lewis, 1197–1–1197–10. University College Cork, Ireland: EWTEC, 2017.

TASK 4
ASSESSMENT OF ENVIRONMENTAL EFFECTS AND MONITORING EFFORTS

PROJECT DURATION
Phase III: 2016 -2020
Phase II: 2013 - 2016
Phase I: 2010 - 2013

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

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

TECHNICAL CONSULTANTS
Pacific Northwest National Laboratory (US), assisted by Aquatera Ltd (UK)

PARTICIPATING COUNTRIES
Canada, China, Denmark, Ireland, Japan, Norway, Portugal, South Africa, Spain, Sweden, United Kingdom and United States of America

FURTHER INFORMATION
http://tethys.pnnl.gov/

OBJECTIVES
Task 4 (known as Annex IV) seeks to be the premier international program engaged in bringing together information and practitioners on environmental effects of marine renewable energy (MRE) development.

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

MEMBER NATION ANALYSTS
Annex IV is characterized by the close involvement of an analyst from each of the 12 member nations. Each analyst was nominated by his/her nation, and is committed to contributing 20 hours per quarter to Annex IV.

Key tasks asked of each analyst include:

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

COLLECTION AND UPDATE OF METADATA
Information is collected for ongoing MRE project sites and research studies in the form of metadata that describe the project or study, the methods and outcomes of environmental monitoring, and provide contact information for the project developers or researchers. Building on the collection of metadata from phases 1 and 2, Annex IV continued to collect information on new wave and tidal projects and for ongoing research studies stored as metadata in Tethys (Table 1). Existing metadata forms were updated by working with the country analysts, developers, researchers, and by using a metadata management system that automates emails asking for annual updates. During 2017, there was a strong effort to update old forms from the initial collection in 2012, especially as these forms have

been particularly difficult to update. Through this focused effort, 28 metadata forms were updated.

DISSEMINATION OF INFORMATION ON ENVIRONMENTAL EFFECTS

Tethys, the online knowledge management system which supports Annex IV material, continues to expand and to increase user interactions. The publically available collection of scientific papers, reports, and other media increased by 411 papers in the last year, for a total of 3,634 entries. The collection includes information on offshore wind effects as well, but a large portion of the papers are exclusively about marine energy development. Over the past year, Tethys has seen an increase in total visits to the site of 11.6%. During 2017, a Tethys Peer Review was completed by soliciting reviews and feedback on the content and functionality of Tethys from the greater Tethys community. A total of 103 reviews were collected through SurveyMonkey. The results of the peer review help understand how users interact with the website and provide a guide to improvements and changes to the system.

WORKSHOPS

During 2017, Annex IV co-hosted two workshops with the Offshore Renewables Joint Industry Programme (OR-JIP). The workshop topics were determined by needs identified by the Annex IV analysts and at the suggestion of regulatory agencies. The first workshop was held on May 9, 2017 in Gasglow, Scotland and brought together 26 researchers, regulators, and developers to discuss management measures for ensuring that environmental permitting of MRE devices could move forward in the face of uncertainty. The workshop output was incorporated into an online tool to help developers and regulators discuss consenting needs and monitoring requirements. The second workshop was held in conjunction with the European Wave and Tidal Energy Conference (EWTEC) in Cork, Ireland on August 31, 2017. This workshop focused on social and economic issues around permitting and brought together 50 participants to examine the data and information needed to consent MRE devices and arrays.

WEBINARS AND EXPERT FORUMS

WEBINARS

Four webinars were held by Annex IV in 2017, each bringing together between 48 and 66 people online to listen to recent research results and plans. The webinars are archived on Tethys; each webinar has been downloaded and viewed hundreds of times after the event:

1. Recent Research of Interest to the MRE Industry, 18 January 2017
2. Artificial Reefs and Benthic Changes in Relation to MRE, 25 April 2017
3. Fisheries Interactions with MRE Devices, 19 June 2017
4. Information Collection and Consenting Processes for Wave and Tidal Deployments – Lessons from the Field, 21 September 2017

Webinars are archived at:
http://tethys.pnnl.gov/mhk-environmental-webinars

EXPERT FORUMS

In addition to environmental webinars, Annex IV held two online expert forums through Tethys. These forums are by invitation only are intended to target specific research issues and interactions that have a high level of uncertainty and that continue to hinder the advancement of research efforts related to consenting, and that are being addressed by multiple research groups worldwide:

1. Standardization of the Data We Collect, 27 February 2017
2. Monitoring around Tidal and Wave Arrays, 4 April 2017
3. Environmental Monitoring around Tidal and Wave Arrays, 12 January 2017

Recordings of the Expert Forums can be viewed on Tethys at: https://tethys.pnnl.gov/expert-forums-marine-renewable-energy

STATE OF THE SCIENCE WORK AND SHORT SCIENCE SUMMARY LITERATURE REVIEW

In 2016, Annex IV produced a "State of the Science" (SOS) report summarizing the current understanding of environmental risks and uncertainties between MRE devices and the marine environment. Eight quick-reference one-page documents— called "Short Science Summaries"—accompany the SOS report. The Short Science Summaries are intended to be examined, and if needed updated, on a yearly basis. With the Annex IV SOS Reports and Short Science Summaries released during 2016, the focus for 2017 was on an active outreach using the SOS report and accompanying products and analysis of new information that warranted product updates.

In 2017, one new Short Science Summary - "Entanglement with Marine Renewable Energy Mooring Lines" - was created, reviewed, designed, and posted on *Tethys*. Outreach activities included a variety of online and in-person presentations, targeted online meetings with agency staff, and numerous less formal presentations and discussions.

The Annex IV team initiated a literature review process in 2017 to evaluate the extent of that new studies and information released since the 2016 State of the Science report might provide new insights. The outcome of the literature review will be used to update the Short Science

Summaries, and to inform the 2020 State of the Science report. The literature review was carried out through systematic searches on *Tethys* and the Web of Science (WOS), and a method was established to systematically evaluate the results. A total of 172 entries of new research were identified in Tethys and 141 in WOS; these records were categorized across five environmental focus areas and refined to 151 records that were relevant to the environmental effects of the MRE industry (118 from Tethys and 34 from WOS). The associated 151 abstracts were reviewed based on a set of six structured questions that helped determine that approximately 34 percent of the records were likely relevant to be considered for one or more updates of SOS one-pagers. The literature review process, findings, results, lessons learned, and recommendation are documented in a separate report.

REGULATOR OUTREACH AND ENGAGEMENT

In 2017, the Annex IV team worked with US MRE regulators to understand the challenges involved in permitting MRE devices, and to begin to address these challenges. A webinar on the Environmental Effects of Permitting MRE Development was held March 29, 2017 for regulators that covered current environmental effects topics facing MRE developments, coupled with the latest research findings The speaker for this webinar was Andrea Copping, PNNL and the webinar is archived on *Tethys*: https://tethys.pnnl.gov/events/environmental-effects-permitting-mre-development-webinar.

Following the webinar, US federal and state regulators were asked to participate in a survey to understand regulators' knowledge of, and preferences for, consenting MRE development. 35 complete responses were received from 15 US federal regulators and 20 US state regulators. Some notable survey results include that regulator's familiarity with wave and tidal technologies is low; that they perceive a difference in impacts between singe devices and arrays and that the risks increases with the scale of the development; and that 25% of state regulators and 36% of federal regulators felt environmental data could "absolutely" be transferred between locations. Based on the survey, progress can be made with the regulatory community through three distinct pathways:

- **Information Dissemination** – There is a need for wide dissemination of what is known about MRE interactions with the marine environment, and that knowledge needs to be put into context to ensure that regulators and other members of the MRE community have a common understanding of the risks.
- **Data Transfer** – A case should be made with regulators that data can be transferred from one MRE project to another, and a set of best practices for data transfer data collection consistency should be developed and promulgated.
- **New Research** – Outstanding questions remaining about interactions of MRE developments and the marine environment will require new research. These questions will be collated throughout the process of regulator engagement and made available to funding sources.

A second webinar was held with regulators to focus on data transferability. The Environmental Effects of MRE Development: Regulatory Survey Results and Next Steps webinar was held on November 2, 2017. This webinar presented the survey results and discussed data transferability and collection consistency with the intent of reducing costs for baseline environmental studies and post-installation monitoring, decreasing uncertainty, and facilitating common understanding to accelerate consenting processes. The speaker for this webinar was Andrea Copping, PNNL and it can be found on *Tethys*: https://tethys.pnnl.gov/events/environmental-effects-mre-development-regulator-survey-results-and-next-steps.

DATA TRANSFERABILITY

Data transferability has become the theme for the Annex IV team in 2018. A white paper on data transferability has been written that details the need for data transferability and collection consistency for environmental effects of MRE data. The white paper is undergoing review. The paper is based on input from regulators, a literature review on data transferability in other industries, and proposes a data transferability framework that could help regulators and other stakeholders move towards transferring data among projects and countries. The paper includes a plan for additional outreach and testing of synthetic datasets with regulators, and taking the results to the larger MRE community at a workshop at ICOE. Following the ICOE workshop, a report is proposed that will develop a set of best practices for data transferability.

FUTURE ACTIVITIES

Future efforts will continue to create a commons around Annex IV and *Tethys* including: the continuation of the Annex IV environmental webinars and the regular addition of new content, metadata, *Tethys* Stories, and *Tethys* Blasts to continue engaging the *Tethys* community. Regular communication and update calls will be held with Annex IV member nation analysts to engage them in Annex IV progress and upcoming activities such as: webinars, conferences and workshops, and soliciting new and updated metadata forms. The major focus over 2018 will be on data transferability and data collection consistency as a pathway to smooth and shorten consenting timelines.

Annex IV expects to have a presence at several conferences including EIMR (Environmental Impacts of Marine Renewables) in the UK; METS (Marine Energy Technology Symposium) in the US; ICOE (International Conference on Ocean Energy) in France and AWTEC (Asian Wave and Tidal Energy Conference) in Taipei.

TASK 6
WORLDWIDE WEB GIS DATABASE FOR OCEAN ENERGY

COORDINATOR
Jochen Bard, Fraunhofer Institute IEE, Germany

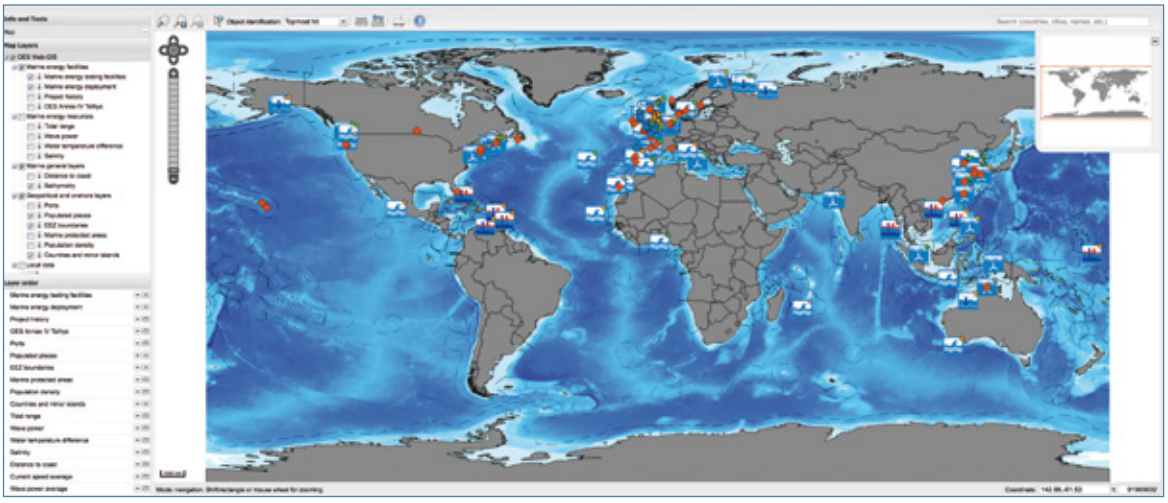
PARTICIPATING COUNTRIES
All Member Countries

FURTHER INFORMATION
https://www.ocean-energy-systems.org/ocean-energy-in-the-world/gis-map/

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

The available information comprises ocean energy facilities, resources, relevant infrastructure and relevant general geopolitical and geographical information, altogether 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.

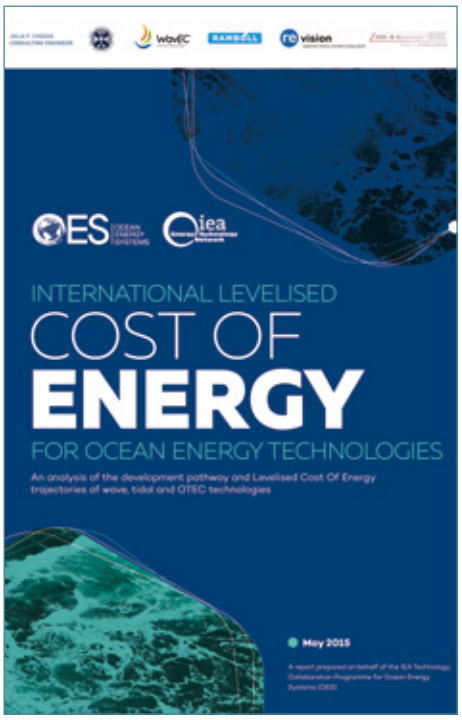


TASK 7
COST OF ENERGY ASSESSMENT FOR WAVE, TIDAL AND OTEC

COORDINATOR
Henry Jeffrey, The University of Edinburgh, UK

PARTICIPATING COUNTRIES
All Member Countries

FURTHER INFORMATION
https://www.ocean-energy-systems.org/oes-projects/



The assessment of the Levelized Cost of Energy (LCOE) for ocean energy devices represents a critical element of understanding in the development of ocean energy array projects. While the cost of existing prototype devices is high, there is scope for significant reductions of the cost of energy.

The first phase of this task was a study done in 2015 which has contributed significantly to the state of the art in knowledge of LCOE and cost reduction trajectories for Wave, Tidal Stream, and OTEC on an international level. Industry consultation has allowed the development of revised cost models for all the technologies considered, producing revised expectations on the development trajectory for each technology.

At the 32nd ExCo meeting (April 2017), Cost of Energy for Ocean Energy Technology was mentioned as one important topic that the ExCo should address. It was therefore suggested to conduct an analysis of the cost of energy from ocean energy system.

The study done in 2015 applied the LCOE methodology developed by the IEA and 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 have been below expectations in the sector. Further progress is needed in order to build confidence in the ocean energy sector, and in each specific technology market.

Technology development and deployments are the main drivers for bringing the cost of energy of ocean energy technologies down; however external factors such as cost reduction of other RES technologies (e.g wind) provide further stimulus for ocean energy to reduce cost quickly.

In order to monitor the evolution of ocean energy costs and to assess the impact of different drivers on the LCOE, it was proposed to undertake a common task on the cost of ocean energy taking into account historical trends, future development and differences among technologies and countries. This work will be developed in 2018.

TASK 8
CONSENTING PROCESSES FOR OCEAN ENERGY

COORDINATOR
Ana Brito Melo, WavEC, Portugal

PARTICIPATING COUNTRIES
All Member Countries

FURTHER INFORMATION
https://www.ocean-energy-systems.org/oes-projects/

The progress of ocean energy projects in all the OES member countries continues to face challenges in relation to consenting processes. This can be detrimental to the sector and may also lead to delays in realising operational projects with consequences for budgeting and real costs to developers.

The Report published by the OES in 2016 presents a summary from each OES member on their national programme activities. Coupled with this, particular emphasis has been placed on investigating the main barriers associated with permitting and licensing with a view to advising regulators and decision-makers on the key needs of the ocean energy sector from consenting processes. Developers were also given the opportunity to provide their views and insights on barriers as experienced by them in consenting of their ocean energy projects to date.

The report has paid particular attention to Marine Spatial Planning and how this is influencing consenting processes and ocean energy device deployments. In addition, OES member representatives provided information on the authorities involved in consenting, the procedures within the consenting process, Environmental Impact Assessment, legislative and regulatory developments, consultation, guidance and test centres. This forms a succinct overview of current practice with the aim of providing a holistic picture of the situation in each OES member country and draw tentative conclusions on whether more integrated approaches to planning are fully operational within OES countries.

Information about consenting processes on Ocean Energy is available at the OES website.

RECOMMENDATIONS

1. Develop messages on what msp can do for the ocean energy sector
2. Request authorities involved in consenting to provide clear information on their respective roles and responsibilities and how they can be contacted
3. Where appropriate, consenting authorities should have an applicable process for consenting an ocean energy deployment and provide information on this (linked to rec.2)
4. Request consenting authorities to identify opportunities for streamlining their consenting processes and/or provide information on how they coordinate their actions with other relevant authorities
5. Tailor consents and associated procedures to better facilitate ocean energy
6. Use strategic environmental assessment
7. Proportionate environmental assessment and monitoring
8. Explore the feasibility of creating initial development zones / pre-defined areas
9. Develop guidance documents for developers that cover the technical aspects of consenting procedures
10. Create promotional materials that explain how ocean energy is different!

Source: O'Hagan, A.M., 2016. Consenting Processes for Ocean Energy - a Report prepared on behalf of the IEA Technology Collaboration Programme for Ocean Energy Systems (OES); www.ocean-energy-systems.org

TASK 9
INTERNATIONAL OCEAN ENERGY TECHNOLOGY ROADMAP

COORDINATOR
Henry Jeffrey, The University of Edinburgh, UK

PARTICIPATING COUNTRIES
All Member Countries

FURTHER INFORMATION
https://www.ocean-energy-systems.org/oes-projects/

The ocean energy sector is now at a stage where numerous prototypes have been deployed. Despite this, there is still a need for many devices to prove long-term reliability and commercially viable energy production levels at array-scale. Much still needs to be done to build confidence in the sector. Identification of existing technologies and areas of knowledge, which are transferable to ocean energy through engagement with other industries, may accelerate the ocean energy sector to earlier commercialisation. Increased collaboration with mature industries will contribute to a successful development pathway and ensure that ocean energy plays a crucial role in the world's future energy mix.

As a first step, this work included a stakeholder engagement process to explore the current challenges faced by the ocean energy sector. Stakeholders from within the sector were interviewed in order to validate known development barriers and to provide a clearer understanding of the benefits of transfer from mature sectors. The

second part of the stakeholder engagement process focused on priority areas of technology for future focus.

The stakeholder engagement process has identified a range of opportunities for a variety of industries and sectors to become involved in ocean energy. Where possible, results have been further divided into specific transferable technologies. These range from technologies that can be directly utilised in the ocean energy sector to those with potential to be utilised, based on similar working principles, but which require adaptation for ocean energy applications.
These results have been included in the final output of this task, which is the "**International Vision for Ocean Energy"** brochure released in early 2017. This publication has been also translated into Spanish.

Source: An International Vision for Ocean Energy 2017, OES

TASK 10
WAVE ENERGY CONVERSION MODELLING VERIFICATION AND VALIDATION

COORDINATOR
Kim Nielsen, Ramboll, Denmark

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

FURTHER INFORMATION
https://www.ocean-energy-systems.org/oes-projects/

Task 10 was initiated in late 2016 aiming to verify and validate numerical models used in the design of wave energy converters and power production calculations, with the following the long-term goals:

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

Experience from similar offshore wind validation/verification projects (OC3-OC5 conducted within the International Energy Agency Wind Task 30) showed that a simple test case would help the initial cooperation to present results in a comparable way. Phase I of this task was then focused on a simple, surface piercing spherical body. Overall good agreement was found among codes with different fidelity levels.

A second meeting was organized in Amsterdam, at 13-14 March 2017, with 13 participants and other 10 experts via webinar. This meeting was hosted by the Danish delegate, Kim Nielsen (Ramboll) and sponsored by the OES, with the following agenda:

1. Review the methodology used and develop methodology further;
2. Propose a generic WEC example and next simulation examples;
3. Discuss existing experimental data sets for validation of numerical results;
4. Select best suited experimental data set for initial test case;
5. Agree on publication strategy.

Further, 3 webinars on 01-07-2017, 28-02-2017 and 19-09-2017 were organized during the year.

PARTICIPANTS IN THE TASK 10 MEETING, AMSTERDAM, 13-14 MARCH 2017

Fabian Wendt	NREL	US
Tim Bunnik	MARIN	NL
Kelley Ruehl	SANDIA National Laboratory	US
Harry Bingham	DTU	DK
Imanuel Touzon	TECNALIA	SP
Kim Nielsen	RAMBOLL	DK
Edward Ransley	Plymouth University	UK
Sarah Crowley	WavEC	PT
Carl-Erik Janson	Chalmers University	SE
Massimiliano Leoni	KTH Royal Institute ofTechnology	SE
Wanan Sheng	UCC	IE
Sarah Thomsen	Floating Power Plant	DK
Pilar Heres	Floating Power Plant	DK

Scientific Paper presented on the European Wave and Tidal Conference EWTEC 2017 and published in their proceedings: Wendt, Fabian, Yi-Hsiang Yu, Kim Nielsen, Kelley Ruehl, Tim Bunnik, Imanol Touzon, Bo Woo Namk, et al. “OES Task 10 WEC Modelling Verification and Validation” In Proceedings of the Twelfth European Wave and Tidal Energy Conference, edited by A. Lewis, 1197–1–1197–10. University College Cork, Ireland: EWTEC, 2017.

TASK 11
OCEAN THERMAL ENERGY CONVERSION

COORDINATOR
Yasuyuki Ikegami, Saga University, Japan

PARTICIPATING COUNTRIES
China, France, India, Japan, Mexico, Korea, Singapore and The Netherlands

OBJECTIVES
A group of 8 Member Countries have interest in this Task: China, France, India, Korea, Japan, Mexico, Monaco and Singapore.
The overall work lead by Japan and assisted by India is carried out by two groups addressing the following topics:

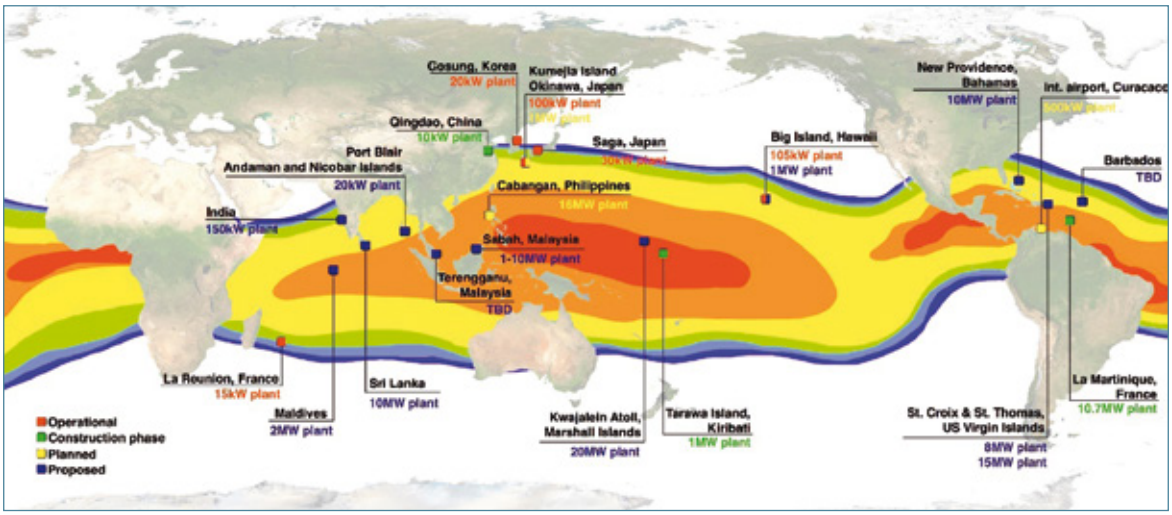
1. Estimation of OTEC potential around the globe (lead by China)
2. Present status and plans of OTEC projects (Lead by Korea)

A state-of-the art report of OTEC activities and projects around the globe has been prepared as a first step to further define a full work program 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 Task 11.

ACHIEVEMENTS
A first webinar was held on the 27 July 2017 at Tianjin, China, organised by the Chinese delegate. The objective of the webinar was to clarify the methodology for the OTEC task. 15 delegates and experts participated in the webinar, where the following topics were discussed:

- Experience in resource assessment of OTEC
- Identification of the goals, activities and next septs
- Methods for estimation of OTEC resource potential

During 2017, a map with information about OTEC power plants was prepared with information about ongoing projects:



Source: https://www.ocean-energy-systems.org/oes-projects

TASK 12
STAGE GATE METRICS INTERNATIONAL FRAMEWORK FOR OCEAN ENERGY

COORDINATOR
Matthijs Soede, European Commission

PARTICIPATING COUNTRIES
All Member Countries

BACKGROUND
It is widely recognised that the ocean energy sector has not met expectations to date, suggesting a more rigorous technical review approach is required which employs improved evaluation methods and metrics than are currently applied in due diligence review and evaluation of ocean energy technologies. Taking the experience and lessons learned from more than two decades of ocean energy technology and market development into account, a detailed monitoring of progress and success should have the following characteristics:

- It is necessary to differentiate between the various needs of the development stages from R&D, Prototype, Demonstration, to Pre-Commercial and Industrial Roll-out;
- Criteria need to be defined which are specific 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 this initial period of focussing on the technological feasibility (Can it be done? Does it work?), where the only metric used was the successful technology evolution to higher TRL levels, economics and other social acceptance criteria have been identified that need to be considered at an early development stage for ocean energy technology to be commercially successful. The current situation is characterised by an ongoing international collaboration on the development of ocean energy technology and the management of the various stage-gated technology development programmes run by funders around the world. This has led to an ongoing need to develop a process for defining appropriate and rigorous metrics for measuring success in a number of critical target areas of OE technology development. Furthermore, associated numerical success thresholds must be identified for each metric which can be applied at each stage of development as stage gate success thresholds.

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

OBJECTIVES
The ultimate objective is to establish a common international stage gate metrics framework to be used by technology developers, investors and funders.

An internationally accepted approach provides device developers, national and international funding organisations, 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.

TASK 13
TIDAL ENERGY CONVERSION MODELLING VERIFICATION AND VALIDATION

COORDINATOR
Srikanth Narasimalu, Singapore

There are many modelling tools developed during recent years for ocean energy resource representation at a macro level. However, there is still lack of common understanding in such predictions to achieve detailed assessment of tidal renewable energy resources at a macro and micro level of a specific site. Moreover, such information about the energy potential and the practical extractable energy are important facts towards major decision making towards sustainable energy harvesting.

Presently assessments are made using computational modelling for micro site assessment, however there is a lack of consensus among modelling community in the type of modelling assumptions, types of software and incoming data requirements. This results in lack of credibility of the final resource information predicted from the computational models. A common effort is required to provide useful guidelines for tidal resource mapping through identifying the present practices and to further compare and contrast the various computational tools for resource mapping to identify the correct approach. This could be achieved through cooperation among an international network of tidal resource mapping experts to discuss and identify a common methodology and verify through few case studies to arrive at guidelines report to benefit the tidal energy adopters and enhance the credibility of modelling practice.

The objectives of this Task is to:
- Survey numerical modelling approach used in tidal-current based energy projects
- Verification and validation of modelling tools & methodology against specific case studies
- Such code to code comparison and detailed methodology studies is expected to provide:
- New set of guidelines, standards which will mitigate uncertainties and confusions involved in modelling ocean renewable energy systems.
- Validated numerical methods and standardization of energy yield estimation
- Reducing risk in project planning and execution of tidal array farms
- Improved tidal energy yield estimate
- Incorporating tidal turbine performance data in the energy yield estimate for more accurate feasibility studies in earlier project stages
- Recommendation of further improvement areas required for the suggested numerical models

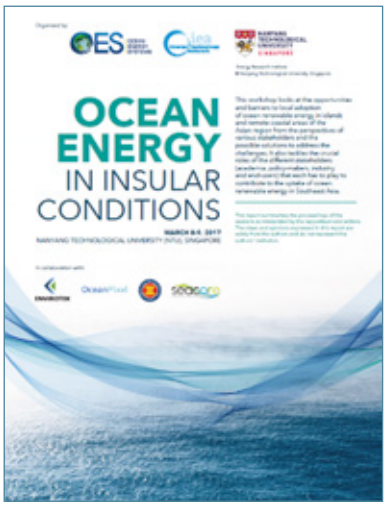
A first webinar was organised and hosted by Energy Research Institute @ NTU (ERI@N), Singapore on 30 June 2017. There were attendees from various international tidal energy working teams from all over the world. The main goal of this workshop is to prepare a Tidal Energy Resource Modelling Guideline report through the study of the various factors affecting the result of the tidal energy resource prediction simulations towards a numerical code-to-code comparison. The workshop was planned as a joint exercise effort to perform an open discussion on the various modelling practices in tidal energy resources.

As great multitude of tools and techniques are used to determine the amount of tidal resources and to quantify the resources available in different parts of the world, establishing a standard in extractable resource modelling can pave the way in promoting the adoption of tidal energy among the various stakeholders, as it can provide confidence in the amount of available resources.

PROPOSALS DISCUSSED BY THE EXCO

OCEAN ENERGY IN INSULAR CONDITIONS

PROPOSAL SUBMITTED BY
Srikanth Narasimalu, Singapore



Ocean energy is relatively new in comparison to other renewable energy sources in Southeast Asia. However, ocean energy activities in the region's water have been gradually increasing in the last decade. Southeast Asian countries is faced with the challenge of providing cleaner energy technologies for the increasing energy demand. On the other hand, in Southeast Asia, one fifth of its population remains to be not connected to the grid and most of these islands and remote coastal areas are heavily dependent to diesel as their source of energy. Generally, the island and remote coastal communities still have a lack of knowledge in ocean energy resources and technologies to utilize the resource. There is a need for research to identify ocean energy resources and their feasible technologies for island electrification.

Therefore, a first workshop on "Ocean Energy in Islandic Conditions" has been organised on 8-9 March 2017, at the Nanyang Technological University (NTU), in Singapore, to facilitate the discussions of the various stakeholders of the ocean renewable energy field specifically those situated in islands or remote coastal areas of the region. The workshop looked at the opportunities and barriers to local adoption of ocean renewable energy in islands and remote coastal areas of the Asian region from the perspectives of various stakeholders and the possible solutions to address the challenges. It also discussed the crucial roles of the different stakeholders (academia, policy-makers, industry and end-users) that each has to play to contribute to the uptake of ocean renewable energy in Southeast Asia.

The results of the workshop were published in the report "Ocean Energy in Insular Conditions".

A second workshop with more international focus will be organised in 2018 to discuss the approach for a new OES Task under this topic.

OCEAN ENERGY JOBS CREATION

PROPOSAL SUBMITTED BY
Yann-Hervé De Roeck, FRANCE

For decision makers, the assessment of the number of jobs related to the development of the Ocean Energy sector is of utmost importance. Figures have been advanced in various roadmaps targeting horizons at 2025, 2030 and even 2050, but in the time since their calculation, not only have numerous devices been designed and tested, but some pilot farms have also been implemented. It is time to assess a first count of the total number of jobs directly related to the sector. The proposed project aims to provide both a working methodology and actual figures of ocean energy jobs creation, with an explanation of the accuracy associated with the results. Planned task includes the analysis, validation and the potential improvement of field data collection methods; the state of the art of available models and assessment of their respective limitations; field data collection and run of the model with input parameters collected and tuned for each participating country.

A first workshop will be organized in 2018 to discuss the approach for this study.

OPEN WATER TESTING

PROPOSAL SUBMITTED BY
European Marine Energy Centre, UK

There are number of marine energy open water test sites currently in operation, construction or planned for development. In 2012, a workshop in Dublin launched OES Task 5 which brought together 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. In late 2013, the European Marine Energy Centre (EMEC) invited all existing and planned wave and tidal energy test sites worldwide to attend a symposium in Orkney, Scotland. Participants at this event represented test sites from around the globe and collaborative research opportunities worldwide were discussed.

Following the success of this initiative EMEC has continued to coordinate annual meetings of this group which is now called International WaTERS (Wave and Tidal Energy Research Sites). At their meeting in Edinburgh in early 2016 the partners identified OES as a way of enhancing the outputs from this group and connecting it with the wider development of the sector.

In the November 2017, the ExCo approved EMEC's proposal to organize a workshop in 2018 with key test centre organisations to build up a detailed programme of work for a new task over the next three years.

ENVIRONMENTAL ISSUES ON OCEAN ENERGY

INTERVIEW WITH

DR. ANDREA E. COPPING

Senior Program Manager for Coastal and Marine Waters
Pacific Northwest National Laboratory

OES: What are the key concerns regarding environmental risks of ocean energy to the marine environment? Is it possible to "retire" some of the environmental effects that have been potentially assigned to ocean energy developments?

Andrea Copping: The key environmental concerns for marine renewable energy (MRE) concern possible interactions between portions of the devices and systems (anchors, foundations, mooring lines, etc.) and marine animals and the habitats that support those animals. As larger scale commercial developments come online, additional concerns may be raised about alterations in ecosystem processes, like sediment transport or water quality, by commercial wave or tidal farms. There are many possible interactions and potential effects that regulators and stakeholders may assign to MRE devices and development; at least a portion of those interactions and effects have been evaluated and generally determined to be unimportant - for example, the release of chemicals from coatings or spills of lubricating oil. We can decrease the importance or "retire" other risks by applying existing research findings - for example, we are close to "retiring" effects of electromagnetic fields [EMF] on organisms. Yet other interactions may continue to be of concern, and will require monitoring of active MRE sites and additional research - for example, collision risk for animals with tidal turbine blades- and still others may require long-term mitigation - for example, siting devices and cable runs to avoid rare habitats like rocky reefs.

Potential environmental concerns may be similar for wave and tidal devices, such as changing behaviour of animals moving past MRE arrays, potential effects of EMFs from cables and energized devices on animal welfare, and disruption of animal behaviour by underwater sound from generators or other moving parts. However, some stakeholders still have concerns that tidal devices could create risk of collision with marine animals that does not apply to WECs as well as the potential for interacting with mooring lines and draped cables in the water column.

OES: So far there are no large arrays of wave or tidal devices operating in the ocean over long periods and therefore many uncertainties currently remain about their interference with marine life. How far do you think knowledge from other industries - buoys and platforms, power and telecom cables in the seafloor, etc. – could be transferable to ocean energy?

Andrea Copping; The oceans have been used for industrial purposes for centuries and the interaction of vessels, navigation markers, piers, underwater installations, and other devices with marine life have been studied as these industries and uses have progressed. Some of these in-

dustrial uses and installations in the oceans are analogous to MRE and can inform our understanding of interactions between MRE devices and systems, and marine life, while others that may resemble MRE devices actually differ in important ways.

Structures like buoys, platforms, piers, and docks have been deployed in the marine environment for centuries, creating hard substrates that can attract fouling communities made up largely of invertebrates and algae. These structures act as fish aggregating devices or artificial reefs, attracting fish and other mobile organisms. Similarly, the presence of offshore oil and gas drilling rigs or offshore wind foundations aggregate fish and other species, and may help explain how animals interact with mooring lines and electrical cables. These structures can also help us predict how changes in wave fields will occur from surface-deployed WECs, and how changes in flow can affect sediment transport and water quality.

Electrical export cables for MRE installations will generate EMF emissions that may affect the orientation, navigation, or hunting ability of electro- or magneto-sensitive species. There have been electrified cables in the marine environment for more than a hundred years that emit measurable EMF signatures, including subsea cables for power and telecommunications, bridges, tunnels, and offshore wind farms.

Anthropogenic noise has been shown to affect marine animal communication, navigation, and hunting. Underwater sound from installing MRE devices, particularly if pile driving is needed, is equivalent to in-water work done for installation of bridges, piers, and other marine infrastructure. MRE development is likely to require installation and maintenance vessels which will generate sound, although these sounds are, like pile driving, typically of short duration. The sounds from operational MRE devices differ somewhat from sound from other industries, but are generally of lower amplitude than other industrial uses such as commercial shipping.

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Not all industry analogs are appropriate for determining potential MRE effects. For example, the risks to marine life from conventional hydropower turbines and rotating ship propellers are not equivalent to risks from tidal turbines. Tidal turbines are generally larger than conventional hydropower turbines, have slower rotational speeds, and slower blade tip speeds, producing lower shear stresses, turbulence, and water pressure, resulting in less dangerous interactions with animals, even if collisions occur. Also marine animals have room to avoid and evade tidal turbines in the ocean, while conventional hydropower in rivers and streams force fish through turbines mounted in dams.

Ship propellers are also poor analogs because they have significantly higher rotational speeds than tidal turbines and can be moving laterally at faster speeds than marine animals can swim.

OES: Would you like to mention any particular interesting research that highlights advances in the ocean energy industry, with respect to environmental issues and responsible development?

Andrea Copping: I have been really proud of the research community for focusing their work on the most critical issues facing the industry, and producing some really innovative and creative studies. For tidal turbines, the issue that slows consenting and potentially will require expensive monitoring studies concerns the risk of marine mammals and fish colliding with moving turbine blades. The most experienced marine mammal researchers have come together with instrumentation specialists to develop ways to observe marine mammals (mostly seals and sea lions) interacting around turbines. Great work has been done in the UK observing seals around turbines in Northern Ireland[1,2], in Scotland at EMEC[3] and the MeyGen array, and in Ramsey Sound, Wales[4,5]. Instrumentation to detect seals approaching a turbine has been developed in Puget Sound, US, and the risk of a collision with a turbine has been modeled in the US and in the UK. Other important work has been done to examine the potential effects of fish aggregating around WECs in Sweden and the US[6]. Another set of studies has measured EMF from cables in the environment in the North Sea[7,8] and in US waters[9], as well as studies on sound outputs from MRE devices[10]. And of course there is so much more that can be found in the Annex IV State of the Science report (https://tethys.pnnl.gov/publications/state-of-the-science-2016), with

all the scientific papers and references found on Tethys (https://tethys.pnnl.gov).

OES: Regulators often request extensive baseline and post-installation data from developers, assuming that at least some of the interactions of the ocean energy devices bear significant risks. How can we help regulators support streamlined processes to this respect?

Andrea Copping: For most nations engaged in MRE development, regulators must follow environmental legislation and regulations that require a significant level of evidence to support conclusions about whether potential impacts are acceptable. Many regulators consider at least some interactions of MRE devices with the environment as highly risky, often due to high uncertainty about these interactions. This uncertainty drives some regulators to take a precautionary approach, requesting extensive pre- and post-installation data collection for each MRE project.

In many cases, the regulators' perception of high risk appears arises from a lack of understanding of the features and operation of MRE systems; the newness of the technologies, many of which bear little resemblance to other industrial uses; and pressure from other stakeholders who fear competition and degradation of the ocean. There are opportunities to help regulators feel more confident in moving forward with less stringent monitoring requirements by providing information and access to research results, through a strong outreach and engagement program. *Tethys*, our online knowledge management system, provides a wealth of information on MRE devices, interactions between marine animals/habitats and devices, and access to many researchers and their work. It is the mission of Annex IV to gather existing information and make it accessible to the community – regulators, concerned stakeholders, researchers, and MRE developers. We host webinars with prominent international researchers; include regulators and other stakeholders in workshops and conferences Annex IV sponsors; and we make outcomes of research deliberations and forums readily available online. The major theme of Annex IV work during 2018 is to examine how data collected at early project locations can be used to inform consenting for later projects, around the world. This *Data Transferability and Collection Consistency* theme has us working closely with regulators to determine their information needs, to understand their acceptance of using data from other jurisdictions, and to develop a set of best practices for extending what regulators can learn from the data collected.

There are opportunities to help regulators feel more confident in moving forward with less stringent monitoring requirements by providing information and access to research results, through a strong outreach and engagement program.

OES: Reducing uncertainty about interactions of ocean energy technologies with the marine environment is a critical step to ensuring that the ocean energy industry continues to grow. In your opinion, what is the path forward for the industry in the face of this scientific uncertainty?

Andrea Copping: Uncertainty surrounding potential effects of MRE development stems largely from a lack of data and understanding of many of the interactions of devices with the environment. With few devices in the water, and even fewer arrays operating, there has not been sufficient time to develop strong predictive models or to rely on a long history of project outcomes. The first step in decreasing uncertainty is to assure that all high quality existing data and information are widely known, and that new information is incorporated into our understanding, as soon as it has been evaluated. In addition, well planned strategic research projects should be undertaken to tackle difficult questions such as the mechanics and outcomes of animals moving close to turbine blades. Strategic research questions should be supported with additional monitoring data, especially around MRE deployments in test centers. Strategic research on MRE interactions will be most valuable if it is planned and executed internationally, bringing together the best researchers, working around deployed devices. As more devices are deployed, our knowledge will increase rapidly; we are currently limited by locations for data collection and research studies.

OES: Annex IV has been running since 2010. After 7 years with continuous collection of data and knowledge on environmental issues of ocean energy projects in the sea, how would you assess the level to which this may have contributed in some countries to drive the processes for consenting projects?

Andrea Copping: It is difficult to quantify the impact that Annex IV has had on the industry around the world. We consider that the continued engagement of more and more countries in Annex IV demonstrates that those nations see value in participating. The 2016 State of the Sci-

ence (SoS) report has been well received with over 4,600 views of the report, in addition to over 500 people who have participated in webinars and conference sessions on SoS. We routinely track metrics on how many people access papers and reports on *Tethys*, as well as how many participate in webinars (either live or in subsequent downloads from *Tethys*); these metrics shows continued steady growth. We reach over 1500 people every two weeks with *Tethys Blast* (https://tethys.pnnl.gov/tethys-blasts), providing updates on papers as well as news and upcoming MRE events. We continue to get enthusiastic participation in our sponsored workshops – for example the recent workshop on social and economic data needed for consenting held around EWTEC in Ireland attracted 36 registrants, while over 50 participants showed up for the workshop. And perhaps best of all, we are told routinely by developers, researchers, regulators, teachers, and other stakeholders, that they use the material gathered by Annex IV, that they value the information, and that it provides a unique resource.

OES: Is it possible to "retire" some of the environmental risks that have been potentially assigned to ocean energy developments? With respect to other anthropogenic causes of the global change (climate, biodiversity, etc.), are we able to set a clear context for the assessment of the relative impacts of ocean energy systems?

Andrea Copping: I believe we can retire certain environmental risks – in fact I think we already have retired some, such as chemical leaching – as more data around devices become available, and as strategic research answers difficult questions. This increase in knowledge and decrease in uncertainty should allow regulators and stakeholders to be more comfortable with accepting that the risks to the marine environment are not significant or can be effectively mitigated. We are well on our way to reaching milestones for retirement for several of these risks; I believe that in future we will hear less concern and fewer requests to monitor EMF emissions, and to examine effects on benthic environments.

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05

INTERNATIONAL SITUATION ON OCEAN ENERGY

BELGIUM

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

Belgium has to increase its share of renewable energy production to 13% of the total consumption by 2020, following the general European Union objective. This share has been growing steadily in the last year. Currently, Belgium's renewable energy share is at around 9%, with a 2020 target of 13%. Main incentives aim at wind energy (onshore and offshore), biomass, biogas and solar energy. The offshore wind energy concessions in the Belgian North Sea will have the biggest impact on renewables, leading up to a total of ±2200 MW of offshore wind power installed by 2020.

A green energy certificate market is implemented to support 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.

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

RESEARCH & DEVELOPMENT

The Laminaria technology could be classified as a surge operated point absorber. The device consists of a cross shaped buoy tethered to the seabed. The horizontal translation and tilting motion of the hull is transferred through the mooring lines to the PTO. The unique selling point of the technology is its active storm protection system. Through the use of the storm protection strategy the device can survive any storm with energy production at nominal power. The device achieves this by regulating its exposure to the passing wave energy. In normal operations the device floats in the water with its top near the surface. When wave power exceeds the level necessary to produce nominal power the device submerges. The device finds the ideal height in the water column where there is still enough motion in the water to

produce nominal power but without undergoing the excessive motion near the water surface. This results in a very effective way of regulating energy input into the device. As a result of the storm protection strategy the device can be optimized to produce optimal in smaller more common waves. This not only translates in a lighter, cheaper and more effective device it also translates in a very high capacity factor.

In 2015, a fully functional ¼ scale prototype has been tested at the sea testing site at Ostend, Belgium. The sea trials have shown the storm protection strategy to be very effective. The device was designed to deliver nominal power of 1 kW at 0.5 m waves. Even though it survived stormy conditions with waves up to 2.7 m who have an energy content of 46 times the waves needed to produce nominal power. Due to the storm protection strategy strains and forces on the device and moorings where limited to the level comparable with 0.5 m waves. During the sea trials a wave to mechanical efficiency of up to 81% was achieved.

During the last year, a 1:16 scale model Laminaria's wave energy converter (WEC) has undergone tank testing at the Coastal, Ocean and Sediment Transport (COAST) laboratory at Plymouth University, as part of the LAMWEC project. Additionally, in May 2016, first lab testing by TTI of full scale mooring belt looked very promising.

Laminaria device at the dock (http://www.laminaria.be/)

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

A test facility was implemented at approximately 1 km from the Harbour of Ostend. The test facility has easy access for deployment and maintenance from the Harbour of Ostend. Wave riders register the available wave climate, an antenna and camera onshore ensure the data connection and visualisations. Navigation buoys protect the test zone from unwanted marine traffic. There is no grid connection installed. There is an interest in installing a monopile structure at the test site, as a monitoring hub and foundation basis for several renewable energy projects.
Information is summarised in the following table:

The construction of the Marine Energy Centre, including a new coastal and offshore basin has begun in 2017. The basin will be of significant importance in the development of wave energy devices. Small to medium scale test devices can be deployed in the basin and operated under wave, current and wind action.

PLANNED DEPLOYMENTS

Laminaria has raised €2M from new investors, QBIC II and PMV, and existing investor CEIP. The funding will support Laminaria to further develop its wave energy generation technology and initiate a full-scale demonstration project at the European Marine Energy Centre (EMEC) in Orkney, Scotland (LAMWEC project).

NEMOS, a German wave energy developer, is focussing on the installation of a large-scale prototype in the Belgian North Sea. With a floater displacing more than 10 m^3 water and a fully equipped powerhouse on an independent structure, the system will generate enough energy to supply several households with electricity.

CANADA

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

Launched in 2011, the Canadian 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 is being made in achieving actions and goals identified by the roadmap, with industry and researchers implementing various activities out of necessity to advance the sector.

While not specific to marine renewable energy, the federal, provincial, and territorial governments established the *Pan-Canadian Framework for Clean Growth and Climate Change*, which addresses key areas for meeting emission reduction targets, driving innovation, and advance climate change adaptation. 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.

Various marine renewable energy research and project development is taking place across Canada, but the hub of activity for the sector continues to be in tidal energy 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.

The province of British Columbia, on the Pacific coast of Canada, has also been spearheading an effort to establish a roadmap for marine renewable energy development. British Columbia's Ministry of Energy & Mines and Petroleum Resources worked with the University of Victoria's West Coast Wave Initiative to develop a roadmap that would support a vision for a scientific and technology hub dedicated to advance the level of understanding, innovation, and business of marine-to-wire renewable energy. Release of the roadmap is forthcoming.

REGULATORY FRAMEWORK

At the federal level, Natural Resources Canada has been conducting broad stakeholder engagement for the development of a legislative framework for offshore renewable energy. The legislative framework will cover renewable energy projects in federal offshore areas.

At the provincial level, the Government of Nova Scotia introduced its *Marine Renewable-energy Act* in 2015, to provide a clear and efficient process to support the sustainable growth of the sector. In the fall 2017, amendments to Nova Scotia's *Marine Renewable-energy Act* were introduced, aimed at allowing for the demonstration of in-stream tidal energy technology in additional areas of the Bay of Fundy – outside of the FORCE berths. The amendments provide a new development pathway, allowing for new entrants into Nova Scotia's tidal energy market, with the flexibility to propose a range of project sizes so long as they are 5 MW or less. Under the amendments, a new permit system will be put in place for demonstration permits up to 5 MW, with no more than 10 MW of total power authorized under the Act.

MARKET INCENTIVES

Under the recent amendments to 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 at a price set by the Minister of Energy. Any utility in Nova Scotia will be required to procure all electricity under the PPA.

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

15-year power purchase agreement with Nova Scotia Power, the provincial electric utility. Under Nova Scotia's community-based feed-in tariff (COMFIT) program, Digby Gut Limited Partnership has one approval and Fundy Tidal Inc. has two approvals for the COMFIT rate of 65.2 cents/kWh for devices in-stream tidal devices under 500 kW to be connected at the distribution level.

The province of Ontario FIT Program continues to include waterpower projects, including river hydrokinetic. Projects must have an electricity generating capacity between 10 kW and 5500 kW. The FIT offers a 40 years contract with a rate of 24.6 cents/kWh.

PUBLIC FUNDING PROGRAMS

NATIONAL FUNDING PROGRAMS:

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 marine renewable energy development:

- $21.9 billion through the Green Infrastructure Fund (including millions for clean energy in remote communities and emerging renewable energy commercialization - more details below);
- $1.4 billion in increased financing support for clean technology available through the Business Development Bank (BDC) and Export Development Canada (EDC);
- $400 million over five years to recapitalize the SD Tech Fund led by Sustainable Development Technology Canada (SDTC);
- $200 million over four years to support clean technology research, and the development, demonstration and adoption of clean technology in Canada's natural resources sector to Natural Resources Canada, Agriculture and Agri-Food Canada, and Fisheries and Oceans Canada (more details below);
- $1.26 billion to a five-year Strategic Innovation Fund;
- $21.4 million over four years starting in 2018-19 to Indigenous and Northern Affairs Canada to support the deployment of renewable energy projects in communities that rely on diesel.

Natural Resources Canada (NRCan) has been leading the development of a number of new targeted national programs with relevance to marine renewable energy, including:

- *Clean Growth in Natural Resources Program:* Budget of $155M over 4 years to support clean technology research, development and demonstrations in Canada's natural resource sectors in the areas of energy, mining, and forestry. As part of this program, NRCan has also established the Clean Growth Collaboration Community, an online platform tool that allows post-secondary institutions, utilities, the private sector, and the public sector to connect with Provincial/Territorial Departments, Federal Research Centres, and other stakeholders to discuss opportunities that could be supported by the Clean Growth Program.

- *Emerging Renewable Power Program:* Budget of $200 million over 5 years, under the Green Infrastructure Fund, with an objective to support the deployment of emerging renewable energy technologies not yet commercially established in Canada. The funding is aimed at supporting deployment of utility-scale renewable energy projects using technologies, which have not yet been deployed commercially in Canada, and expanding the portfolio of commercially-viable, investment-ready technologies available.

- *Clean Energy for Rural and Remote Communities Program:* Budget of $220M over six years (starting in 2018/19) under the Green Infrastructure Fund, with an objective of reducing reliance on diesel in rural and remote communities and industrial sites by supporting the transition to more sustainable energy solutions.

PROVINCIAL FUNDING PROGRAMS:

Nova Scotia's Offshore Energy Research Association (OERA) collaborated with Nova Scotia Department of Energy and NRCan to develop a $1.25 million research call addressing knowledge gaps and challenges associated with tidal energy development in Canada. The funding included $1M from NRCan and $125,000 from Nova Scotia Department of Energy and OERA.

Innovacorp, a Nova Scotia organization with a mandate to identify, fund, and foster innovative start-ups, developed three ocean technology funding programs with applicability to marine renewable energy:

- *Demo at Sea Program:* Allows Nova Scotia companies to demonstrate pre-commercial ocean technologies in a real-life setting. The program provided access to the Flume Tank at the Marine Institute in St. John's, Newfoundland and Labrador and FORCE's Fundy Advanced Sensor Technology (FAST) Platform, which enables testing and demonstration in high flow environments.
- *Early Adopter Program:* Provides Nova Scotia ocean technology companies with up to $20,000 each towards the first deployment and testing of a product with an early adopter customer.
- *OceanTech Development Program:* Provides Nova Scotia companies with up to $20,000 each to address short-term milestones in their technology development plan.

Under the Pan-Canadian Framework on Clean Growth and Climate Change, British Columbia and the Government of Canada have agreed to work together to spur the development and commercialization of new technologies that will reduce emissions and create jobs for Canadians. In April, the governments of British Columbia (BC) and Canada partnered to establish a $40 million joint fund with contributions from BC's Innovative Clean Energy (ICE) Fund and Sustainable Development Technology Canada (SDTC). The funding available through this joint fund will leverage federal, provincial and private sector investments. The $20-million provincial contribution comes from the ICE Fund. The federal contribution will be provided through the SD Tech Fund, managed by SDTC.

The parties will conduct a joint call over a three-year continuous intake period to seek out clean-energy projects and technologies that will mitigate or avoid provincial greenhouse gas emissions, including prototype deployment, field testing and commercial-scale demonstration projects.

RESEARCH & DEVELOPMENT

ACADIA TIDAL ENERGY INSTITUTE (ATEI)

The Acadia Tidal Energy Institute (ATEI) at Acadia University continues to support sustainable tidal energy development via risk reduction and informed decision making. Activities led by ATEI in 2017 included:

- Launch of a multi-institutional project "Environmental Monitoring, Modelling and Forecasting Infrastructure for In-stream Tidal Energy" led by Acadia with partners Dalhousie University, University of New Brunswick and Memorial University.
- Preparation and provision of model data to assist with Cape Sharp Tidal marine operations, drifter-ADCP surveys for tidal energy resource assessment, with Luna Oceans & Dalhousie;
- Drifter-hydrophone system design and proof of concept testing in Minas Passage/Channel for detection of harbour porpoises;
- Analysis and interpretation of active hydroacoustic datasets collected with fish detection sonars housed on a FAST platform at the FORCE test site;
- In-depth analysis of fish tracking datasets for the determination of fish – turbine encounter probabilities at FORCE.
- Multiple publications covering issues such as governance, funding and financial supports, social acceptance, stakeholder engagement, Indigenous rights and ownership, and fish interactions and behaviour.

WEST COAST WAVE INITIATIVE (WCWI)

The West Coast Wave Initiative (WCWI), out of University of Victoria's Institute for Integrated Energy Systems (IESVic), completes high resolution wave resource assessments, detailed wave energy converter (WEC) technology simulations and both short-term and long-term electrical system integration studies. The WCWI has developed and validated a high resolution wave model of the British Columbia coast that is utilized as both on 12-year hindcast and a 48-hour forecast.

Over 2017, WCWI continued its efforts to support cutting edge wave research and development efforts for governments, technology and project developers across the globe. In November, WCWI received $1.4 million from Western Economic Diversification (WD) to establish the Pacific Regional Institute for Marine Energy Discovery (PRIMED), which will lead work to eliminate the uncertainty and risk for "first-of-a-kind" community based marine renewable energy projects.

PRIMED will make use of extensive wind, wave and tide data and consolidate it with new data gathered by sensors on the new Canadian Pacific Robotic Ocean Observing Facility (C-PROOF). Using simulations, PRIMED will provide detailed predictions of energy supply prior to the deployment of devices.

In April, the WCWI released a co-authored report with the Pacific Institute for Climate Solutions, *Wave Energy: A Primer for British Columbia*, summarizing key research findings about the magnitude of BC's wave energy potential and the challenges and opportunities of the sector. Funding through the Natural Sciences and Engineering Research Council of Canada (NSERC) was also received to support further work with a number of wave-technology companies and modeling of the wave energy resource in British Columbia. Through WCWI's work over the past years, there is now enough detailed information on the height, frequency and direction of its coastal waves to start developing and testing energy converters in the ocean.

OFFSHORE ENERGY RESEARCH ASSOCIATION (OERA)

The Offshore Energy Research Association (OERA) in Nova Scotia continues to support research that will facilitate the sustainable development of tidal energy in the province and Canada. In 2017, OERA led and supported a number of activities including:

- Supported five collaborative research projects under the areas of environmental effects monitoring, marine operations, and cost reduction technologies in collaboration with Natural Resources Canada and Nova Scotia Department of Energy;
- An update to the (2011) Marine Renewable Energy Infrastructure Assessment to bring to current, projected needs for the tidal industry relating to port options around the Bay of Fundy;
- New research on the financial support mechanisms available to project developers to aid in the growth of the Canadian tidal sector (Acadia University);
- New software development in tug propulsion systems modelling for use in optimizing tidal energy marine operations (DSA);
- Improved understanding of the probability of encounter between striped bass populations and a turbine in the Bay of Fundy (Acadia University);
- New findings on how striped bass behave, move and respond to an operating turbine in a (controlled) laboratory environment (Dalhousie University);
- Testing of drone technology and its use as a novel and cost effective tool for tidal energy site characterization.

OERA also recently entered a Memorandum of Understanding (MOU) with the Natural Sciences and Engineering Research Council of Canada (NSERC) that will jointly fund marine renewable energy research projects in Nova Scotia. These projects will support academic research carried out in collaboration with Canadian companies over the next three years.

CANMETENERGY/NRCAN AND NATIONAL RESEARCH COUNCIL (NRC)

CanmetENERGY/NRCan have been working on collaboratively to develop marine energy resources atlas for province of British Columbia (BC). This project aims to complete a comprehensive assessment of tidal, wave and river hydrokinetic energy resources throughout BC. It will assemble a geo-spatial database containing best-available information on wave, tidal and river hydrokinetic resources combined with other relevant socio-economic datasets and develop a specialized geo-spatial analysis, mapping and decision support system to support and inform stakeholders in identifying and evaluating sites for prospective development. It will estimate unit cost of energy for wave, tidal and river hydrokinetic resources and estimate the potential future market penetration for marine renewables in the province. NRCan has initiated five-year collaborative research projects in advancing river hydrokinetic energy with NRC, academia, marine energy industry and Canadian Hydrokinetic Turbine Test Centre. Project aims to develop methodology to identify potential sites in a river stretch using radar satellite images taken during winter months where fast flowing river sections in Canada are not likely to freeze. Second objective of the project is turbine performance monitoring to collect data of operating for a full season to improve understanding of energy production, performance and reliability of river hydrokinetic system and to investigate how to improve energy extraction efficiency of cross-flow turbine. Third objective is to understand multiple turbine array interactions and spacing between turbines to optimize energy extraction from a stretch of river resource to develop guidelines for turbine array configuration.

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

Canada has wave, tidal, and river current energy resources spanning the country. As a result of the opportunities presented by developing these resources, there are test sites available to support research and development of each marine renewable energy technology:

TIDAL CURRENT TURBINE TEST SITE

The Fundy Ocean Research Center for Energy (FORCE) is Canada's leading research center for in-stream tidal energy, located in the Bay of Fundy, Nova Scotia. FORCE works with developers, regulators, and researchers to study the potential for tidal turbines to operate within the Bay of Fundy. As part of its mandate, FORCE has undergone baseline environmental studies, environmental effects monitoring, and applied research since 2009. In addition, FORCE created the Fundy Advanced Sensor Technology (FAST) program to advance efforts to monitor and characterize the FORCE site and improve marine operating methodologies to support research and turbine-related operations. FORCE hosts five technology developers at its site and provides subsea and onshore electrical infrastructure to deliver power to the grid. The five developers have been awarded and have received feed-in tariff approvals from the Province of Nova Scotia, totaling 22 MW to be developed at the FORCE test site. In 2017, Cape Sharp Tidal successfully disconnected and recovered its 2 MW OpenHydro turbine from the FORCE site. This was the first grid-connected tidal turbine to operate at the FORCE site. Cape Sharp is currently inspecting and upgrading the turbine and intends to redeploy in 2018. Other developers scheduled for testing at the FORCE site include Minas Tidal, Black Rock Tidal Power, Atlantis Operations Canada, and Halagonia Tidal Energy (DP Energy).

RIVER HYDROKINETIC TURBINE TEST SITE

The Canadian Hydrokinetic Turbine Test Centre (CHTTC) in Manitoba allows turbine developers to test turbine prototypes and increase their technology readiness level. In 2017, CHTTC tested and connected the redesigned New Energy Corporation's 25 kW device to the Manitoba Hydro grid in preparation for deployment at Sagkeeng First Nation. The project experienced delays due to certification issues for the marine power cable and the low frequency power electronics. CHTTC also conducted long-term flow measurements and improved on the filtering of ADV data to characterize energetic river flows. Support was also provided to companies developing marine turbines. As an important step to develop a Canadian resource map of potential energetic sites near remote communities reliant on diesel, in collaboration with NRCan, CHTTC used RadarSat II to capture radar images of four Indigenous communities. An autonomous data acquisition system funded by NRCan was developed to remotely monitor the 25 kW New Energy turbine powered by the turbine and solar panels.

WAVE ENERGY CONVERTER TEST SITE

The College of the North Atlantic (CNA) operates the Wave Environment Research Centre (WERC) in Lord's Cove on the south coast of the island of Newfoundland. The Centre was established to conduct research in the development of a wave-powered water pump coupled to a novel shore-based aquaculture system. Currently, there are six fully permitted mooring sites (at depths of 6 to 30 m) available within 1.5 km from shore. The site has collected more than three years of weather and wave environment data. In 2017, WERC conducted sea trials of its wave pump, a device intended to provide a flow of sea water to an onshore aquaculture farm. Over the last 6 years of developing the project, it has engaged over 200 college and university students and over 20 scientists, technicians and faculty. WERC recently upgraded its wave measurement capability with a second Nortec AWAC and telemetry system, while Rutter Inc. has deployed extensive radar-based wave measurements at the site. Atmocean, a US-based wave energy developer, deployed its wave powered pump at WERC for a month of preliminary testing, and NRG Systems is currently evaluating the marine durability of several of its meteorological sensors.

WERC's Wave pump being prepared for deployment

OPERATIONAL PROJECTS

The 20 MW **Annapolis Royal tidal barrage power plant** was commissioned in 1984 and continues to operate today. It is owned and operated by Nova Scotia Power (a subsidiary of the utility company EMERA). Annapolis Royal is the only commercial tidal power plant in North America.

Cape Sharp Tidal installed the first of their two turbines into the Minas Passage at the FORCE site in Nova Scotia in 2016, resulting in $33 million of investment in the local supply chain during building and installation phases. The turbine was retrieved in June 2017 to allow for upgrades to its turbine control center (TCC). This was the first time OpenHydro's pioneering TCC technology has been used anywhere in the world, an important step in advancing the ability to generate electricity from multiple turbines at sea and export to shore via a single export cable. Plans are underway for Cape Sharp's next deployment and a demonstration array of two interconnected 2 MW turbines. Since the turbine deployment, Cape Sharp and FORCE have issued three environmental monitoring reports based on their Environmental Effects Monitoring Programs (EEMP).

Cape Sharp Tidal's 2 MW turbine in port after successful recovery.

Mavi Innovations is approaching full commissioning of its Mi1 floating tidal turbine at Blind Channel Resort and Marina in British Columbia, aimed at offsetting the operator's use of diesel fuel. The turbine is integrated into the existing diesel network, along with an additional smart diesel gen-set and battery storage. In June, Mavi installed its mooring system, lay the cable, and began work to commission the hybrid power system. Mavi will be working with project partners including the University of Manitoba to measure the performance and assess the feasibility of this hybrid tidal power system.

Mavi Innovations' Mi1 floating tidal turbine at Blind Channel, British Columbia

New Energy Corporation partnered with Sagkeeng First Nation in Manitoba to install a 25 kW hydrokinetic turbine in the Winnipeg River. In July, work commenced to test the turbine and installation will begin in early 2018. In partnership with CHTTC and Natural Resources Canada/CanmetENERGY, this project is fully equipped to monitor the turbine performance.

New Energy Corporation turbine preparing for commissioning at Sagkeeng First Nation in Manitoba.

Many Canadian technology developers have also been working with international partners and have deployed their technologies in other countries.

PLANNED DEPLOYMENTS

In the Bay of Fundy, there are several in-stream tidal energy planned deployments at the FORCE site, with five technology developers planning deployments between 2018 and 2019 who have received approvals from the Government of Nova Scotia: Cape Sharp Tidal, with the project's next deployment planned for 2018; Black Rock Tidal Power, up to 5.0 MW in 2019; Minas Tidal Limited Partnership, up to 4.0 MW with deployment beginning in 2018/19; Atlantis

Operations Canada, up to 4.5 MW with deployments beginning in 2019; and Halagonia Tidal Energy, up to 4.5 MW with deployments beginning in 2019.

Additional technology and project developers are pursuing opportunities in Nova Scotia and British Columbia:

- Following their successful test of the Kinetic Keel technology in the Bay of Fundy, **Big Moon Power** continues to improve their design. Big Moon has made some important strides to lower costs and produce an end product that can compete across all renewable energy spectrums. Big Moon is aiming to deploy its technology in Nova Scotia with a commercial scale demonstration project mid-way through 2018.
- **Jupiter Hydro** has partnered with Hatch, a Canadian Engineering company, to test and prove functionality of its in-stream tidal technology with the future intention of building and deploying two 2.5 MW turbines for potential deployment in Nova Scotia.
- **Yourbrook Energy Systems** completed its initial pilot project with its small-scale tidal prototype (up to 80 kW) in Haida Gwaii, British Columbia. The data collected supports the methodology applied to the technology and the prototype is now going to be upgraded for use in a scaled demonstration project, aimed at supporting future commercialization.
- As a result of the successful deployments in 2016 and 2017, **NeptuneWAVE** (formerly Mermaid Power Corporation) pursued further approvals and now has an investigative use license for the testing of its 200 kW Neptune 5 wave energy device in Georgia Strait, British Columbia in early 2018.

OTHER RELEVANT NATIONAL ACTIVITIES

IEC TC 114

Canada has been actively engaged in the standards development process for marine renewable energy since the inception of the International Electrotechnical Commission Technical Committee 114 (IEC TC114) in 2007, which is the international standards organization for marine and river hydrokinetic energy. The Canadian Standards Mirror Committee/TC114, in collaboration with external partners, has completed 11 research projects investigating key questions to support standard development in wave energy, tidal energy, and river hydrokinetic energy systems. In the last year, there have been several developments including two new standards published relating to enhanced wave resource assessment and design requirements, bringing the total number of standards published to 8. Another draft standard on guidance for wave energy prototype development is in final stage of voting for publication. In addition, a new team was formed to begin drafting a standard on measurement of mechanical loads.

NEW INTERNATIONAL COLLABORATIONS

In 2016, Marine Renewables Canada entered into a MOU with Marine Energy Wales and over the course of 2017, the associations have been working very closely under this MOU – sharing information and knowledge about the sector, participating in joint webinars, and participating in respective conferences. The MOU marks an important step towards positive collaboration between the two countries and joint activities are in planning for 2018.

CONFERENCES

The Marine Renewables Canada Annual Conference will be held November 21-22, 2018 in Halifax, Nova Scotia.

CHINA

SUPPORTING POLICIES FOR OCEAN ENERGY

In 2017, the State Oceanic Administration (SOA) released the "13th Five-Year Plan for Marine Renewable Energy (2016-2020)", which sets out the key principles, specific actions and enablers needs to deliver upon China's potential in marine renewable energy. By 2020, 4 marine renewable energy demonstration districts will be built; the total installed capacity of marine renewable energy will be more than 50 MW. The National Development and Reform Commission (NDRC), the Ministry of Finance (MOF) and the National Energy Administration (NEA) released the "Regulations for the Trial Implementation of Renewable Energy Green Power Certificate" in February.

The SOA and MOF continue to fund the marine renewable energy utilization and development, a total budget of RMB 137 million was granted for 4 marine renewable energy projects. To date, China has committed approximately about RMB 1.25 billion to marine renewable energy RD&D since 2010.

NATIONAL STRATEGY

The "13th Five-Year Plan for Marine Renewable Energy (2016-2020)" was released by the SOA in December 2016. The Plan sets out the key principles, specific actions and enablers needs to deliver upon China's potential in this area. The over-arching vision of the Plan is to i) Promote the demonstration and application of marine renewable energy, ii) Focus on the breakthroughs in key technologies, iii) Improve the technology levels of marine renewable energy, iv) Strengthen the construction of public service platform, and v) Foster international cooperation in development of marine renewable energy". By 2020, 4 marine renewable energy demonstration districts will be built; the total installed capacity of marine renewable energy will be more than 50 MW.

The "13th Five-Year Plan for Development of Oceanic Economy" was released by the NDRC and the SOA in May 2017. The Plan highlights: i) Improving offshore wind industrial layout, ii) Encouraging construction of offshore (Deep sea) wind plant, iii) Establishing the standards system, iv) Advancing marine renewable energy demonstration projects, v) Developing key technology components, vi) Accelerating the construction of island projects for multi-energy power supply based on marine renewable energy and the building of demonstration districts

The National Energy Administration (NEA) released the "13th Five-Year Plan for Energy Technology Innovation" in December 2016. Accordingly, the "marine renewable energy key technologies utilization and demonstration project" is accepted into the 15 demonstration projects scope.

The NEA and the SOA released the "Measures for the development of offshore wind power" in December 2016. The implementation of the Measures will be led by the NEA and the SOA. The NEA is actively overseeing its implementation.

MARKET INCENTIVES

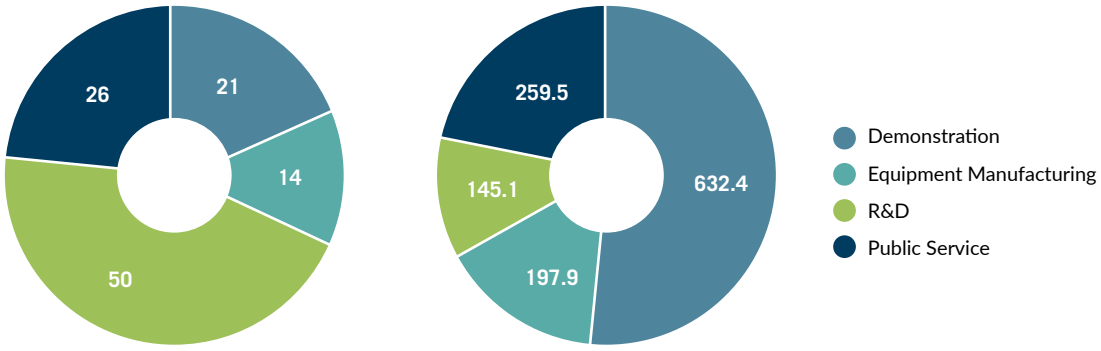
The NDRC, the Ministry of Finance (MOF) and NEA released the "Regulations for the Trial Implementation of Renewable Energy Green Power Certificate" (REGPC) in February 2017. The Regulations highlights "Establishing the Voluntary Subscription System for REGPC, Approving and Issuing the REGPC, Improving the Regulations for REGPC Purchase and Sale, and Strengthening management of the REGPC Systems". Accordingly, the Regulations will be led by the NEA and the National Renewable Energy Information Management Centre (NREIMC). The NREIMC is in charge of issuing and managing REGPC through the Renewable Energy Project Management System (REPMS, NEA).

PUBLIC FUNDING PROGRAMMES

The SOA and MOF continue to fund the marine renewable energy utilization and development. The SOA reiterates the focus on stimulating industry-led projects for the development and deployment of marine renewable energy devices

and systems through the support of the Special Funding Plan for Marine Renewable Energy (SFPMRE). In 2017, a total budget of RMB 137 million was granted for 4 marine renewable energy projects, including the 1 MW wave energy demonstration project, the tidal stream energy island demonstration project, the power supply system provided by wave energy for offshore devices, and the power supply system provided by wave energy for offshore cage.

As of September 2017, more than 111 marine renewable energy projects have been supported by SFPMRE, funding a total of RMB 1.25 billion, which fully played a guiding role of government finance in the aspects of support for national industrial structure adjustment, cultivation of strategic emerging industries, safeguard of national energy security and exploration of energy structure adjustment etc. In general, the SFPMRE has been promoting the significant improvement of marine renewable energy technologies in China.



PROJECTS ALLOCATION

INVESTMENT ALLOCATION
(RMB million)

RESEARCH & DEVELOPMENT

WAVE ENERGY

In 2017, supported by the SFPMRE, the Youlian shipyard (Shekou) Co. Ltd. and the Guangzhou Institute of Energy Conversion (GIEC) have been developing a power supply system provided by wave energy for offshore cage. The floating cage will be powered by wave energy (60 kW) and solar energy (30 kW), and the cabins could also be used for workers accommodation or storage rooms. The system is suitable for different depth from 15 m to 100 m, and the system will be deployed for sea trial in 2019.

OTEC

Supported by the SFPMRE, the National Ocean Technology Centre (NOTC) is developing a power system (200 W) of instrument based on OTEC, the maximum operating depth is 500 m. NOTC completed the installation and sea trial of the power system in 2017.

OCEAN SALINITY ENERGY

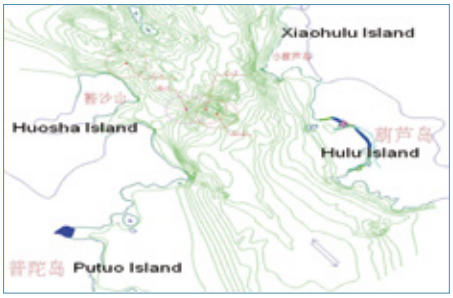
Supported by the SFPMRE, the Ocean University of China (OUC) is developing an ocean salinity energy power system using pressure retarded osmosis technology. The OUC completed the design and testing of the system in 2016. The system achieves the power of 100 W with its total efficiency over 3%.

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

NATIONAL SMALL SCALE TEST SITE IN WEIHAI, SHANDONG:

Developed by the NOTC, the test site completed the construction of the monitoring centre and the deployment of the ocean observation system in 2017.



TIDAL CURRENT ENERGY TEST AND DEMONSTRATION SITE IN ZHOUSHAN, ZHEJIANG:

The test and demonstration project was developed by the China Three Gorges Corporation (CTGC) in June 2015, with the investment of RMB 135 million. Three test berths and a demonstration berth will be built in the site. The CTGC completed the purchase of a tidal current energy turbine by international bidding in 2017.

WAVE ENERGY TEST AND DEMONSTRATION SITE IN WANSHAN, GUANGDONG:

The test and demonstration project was developed by the GIEC in July 2017. Three WEC devices will be deployed in the site in 2019, and one of them will be purchased by international procurement. The total installed capacity is over 1 MW. The investment is about RMB 150 million.

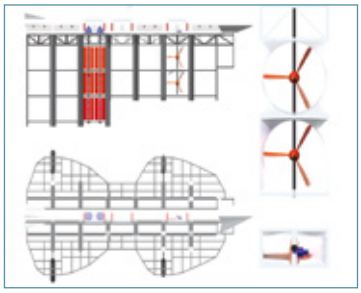
OPERATIONAL PROJECTS

SHARP EAGLE WAVE ENERGY DEMONSTRATION PROJECT (GIEC):

Funded by the Special Fund for Strategic Technology Pilot of CAS, the Sharp Eagle (100 kW) was upgraded by the GIEC for better providing power to remote islands demonstration. The new hydraulic cylinders were installed, with higher corrosion resistant performance and reliability, and new WECs were installed in the platform, the total installed capacity of the WEC is over 200 kW. The upgraded Sharp Eagle-Wanshan was deployed near Wanshan Island for sea trial in March 2017. The amount of electricity accumulated was more than 50 MWh until December 2017.

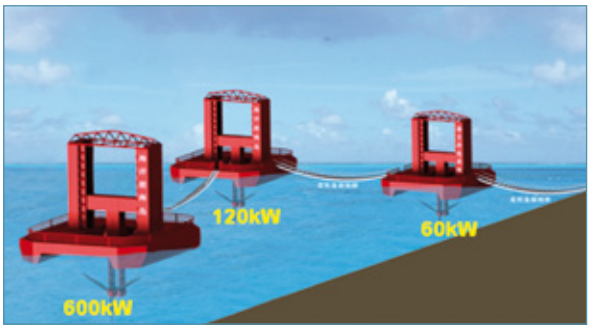
LHD TIDAL CURRENT ENERGY DEMONSTRATION PROJECT:

Seven turbines will be installed on the platform; the total installed capacity will be 3400 kW. To date, 2 turbines were installed on the platform, and connected to the grid in August 2016. The amount of electricity accumulated was more than 450 MWh until December 2017. IO&M has been conducted by LHD since March 2017, and the turbines were deployed in August 2017. Funded by the SFPMRE, a new 300 kW horizontal-axis turbine is being developed by LHD and Blue Shark Power System (BSPS), and the new turbines will be installed and tested on the platform in July 2018.

ZHAIRUOSHAN TIDAL STREAM ENERGY POWER DEMONSTRATION STATION:

In 2015, the Zhejiang University (ZJU) installed a 120 kW tidal stream turbine near the Zhairuoshan Island (with their 60 kW turbine already deployed in 2014). To date, the total power generation has accumulated more than 30 MWh. In 2017, the ZJU was funded RMB 15 million by the SFPMRE to develop a new 600 kW turbine. In the future, the station can serve as a testing platform for tidal current energy turbines.

PLANNED DEPLOYMENTS

Guo Dian United Power Co., Ltd (GDUP): GDUP is developing a 300 kW tidal stream turbine based on the turbine developed by the ZJU. GDUP has completed the commissioning test for the turbine, and will deploy the device near the Zhairuoshan Island in 2018.

Hangzhou Jianghe Hydro-Electric Science & Technology Co., Ltd (HJHEST): The HJHEST is developing a 300 kW tidal stream turbine based on a two-way turbine developed by the Northeast Normal University (NNU). HJHEST has completed the design and test for the turbine, and will deploy the device near the Zhairuoshan Island in 2018.

RELEVANT NATIONAL EVENTS

The 6th China Marine Renewable Energy Conference (CMREC), hosted by the NOTC and the Administrative Centre for Marine Renewable Energy (ACMRE), was held on 25 May 2017 in Zhuhai, Guangdong Province. The theme was "Innovation-driven development of MRE". More than 200 government organizations, universities, institutes, companies and stakeholders participated in the conference.

DENMARK

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The lack of Danish national action plans and targets has been discussed in the forum of the Danish Partnership for Wave Power. In 2012, the partnership developed the strategy for development of wave energy in Denmark. During the fall of 2017, the partnership summarized this strategy in a five-page document and, on November 2017, a small delegation representing the chairman of the partnership for wave power and three wave energy developers presented their wishes in the Danish Parliament, which included five key points:

Delegation including Per Resen (Resen Waves), Kim Nielsen (Chairman of the Partnership), Michael Henriksen (Wave Piston), Anders Køhler (Floating Power Plant) at the Danish Parliament.

1. Long-term support must be secured for existing test sites such as DanWEC, which was established with EUDP Greenlab Grant in 2012.

2. The "ForskVE" model should be revived on relevant projects, so the funding and support is conditional on demonstrating delivery of an agreed electricity production depending on wave conditions, thus creating a focus on costs, performance and operational safety.

3. To ensure and increase the rate of public co-financing up to 70% for the cost of building the demonstration plants of the most promising competing wave power concepts.

4. The introduction of additional tariffs (€ 300/MWh) for wave power (time- and production limited), which can stimulate investors to invest in the most promising concepts, which then can compete on the ability to produce energy and earn money to expand business.

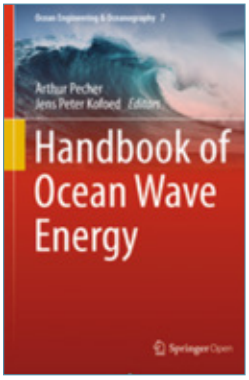
5. Ocean space planning in Denmark should include wave power plants to ensure that future electrical infrastructure development in the North Sea is able to benefit both wind and wave power, with due consideration of environmental and societal aspects.

PUBLIC FUNDING PROGRAMMES

There are two national funding programmes under which ocean energy developers can seek funding for R&D and system development; these are EUDP and Innovation Fund Denmark, both invest in new knowledge and technology creating growth and employment in Denmark.

RESEARCH & DEVELOPMENT

Aalborg University (AAU) Wave Energy Group, headed by Arthur Pecher and Jens Peter Kofoed, has published a new open access book entitled Handbook of Ocean Wave Energy. It includes contributions from a range of experts dealing with topics like Cost of Energy, Resources, WEC hydrodynamics, Moorings, PTOs, Experimental Testing and Numerical Modelling. The book can be downloaded from the link: https://link.springer.com/book/10.1007/978-3-319-39889-1



Open source book on Wave Energy

There are a number of R&D projects on-going, one is the co-operative project on "Mooring Solutions for Large Wave Energy Converters" led by AAU in co-operation with Chalmers University, and Tension Technology International and the developers of the WECs Floating Power Plant (FPP), Wave Dragon (WD), Leancon and KNSwing. The objectives of the project are to design, test and develop cost efficient mooring solutions for large, slack moored, floating wave energy converters (WECs), and to build national competences in design and modelling of mooring systems for WECs.

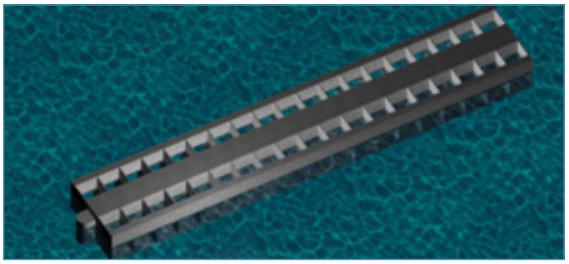
The second project concerns "Resource Assessment, Forecasts and WECs O&M strategies at DanWEC", also led by AAU with the partners DHI and DanWEC. The project is dealing with a detailed assessment of the Wave Energy Resource of DanWEC, and a tool able to forecast the wave conditions is being developed (AAU, DanWEC, DHI).

The new Wave Basin at AAU is included as an infrastructure under the EU supported MarRINET2 programme. So far three MaRINET2 projects have been allocated to AAU. AAU further leads the project "New Material for Wave Energy Substructures", a project supported by the Energiteknologiske Udviklings- og Demonstrationsprogram (EUDP). The project runs from 2016 to 2020 (http://www.newmaterialwes.aau.dk/). The ultimate objective is to develop a new kind of material that will allow protecting the sub-structure of wave energy converters from rust and scour in a completely innovative way. The material proposed for investigation is called Biorock. The novel technology uses electrolysis of seawater to precipitate calcium and magnesium minerals to 'grow' a crystalline coating over artificial structures, typically expanded steel meshes of any desired shape and size. At the present stage, after 1 year of laboratory tests at the Chemical Engineering Department, AAU Esbjerg, we are about to deploy two small models in Nissum Bredning and Hanstholm, to monitor the mineral accretion in cold waters.

Floating Power Plant A/S (FPP) develops floating wind platforms that integrate wave power. FPP has successfully tested a grid connected ½ scale prototype over 2 years and is currently developing the technology for 3 commercial projects in Scotland, Wales and Ireland. The projects are led by project developer DP Energy.Floating Power Plant has been able to access the test facility Oceanide in France, via MaRINET2, to perform tests of sections of their wave energy absorbers in scale 1:30.

Floating Power Plant

Floating Power Plant testing a section of its wave energy model



KNSwing

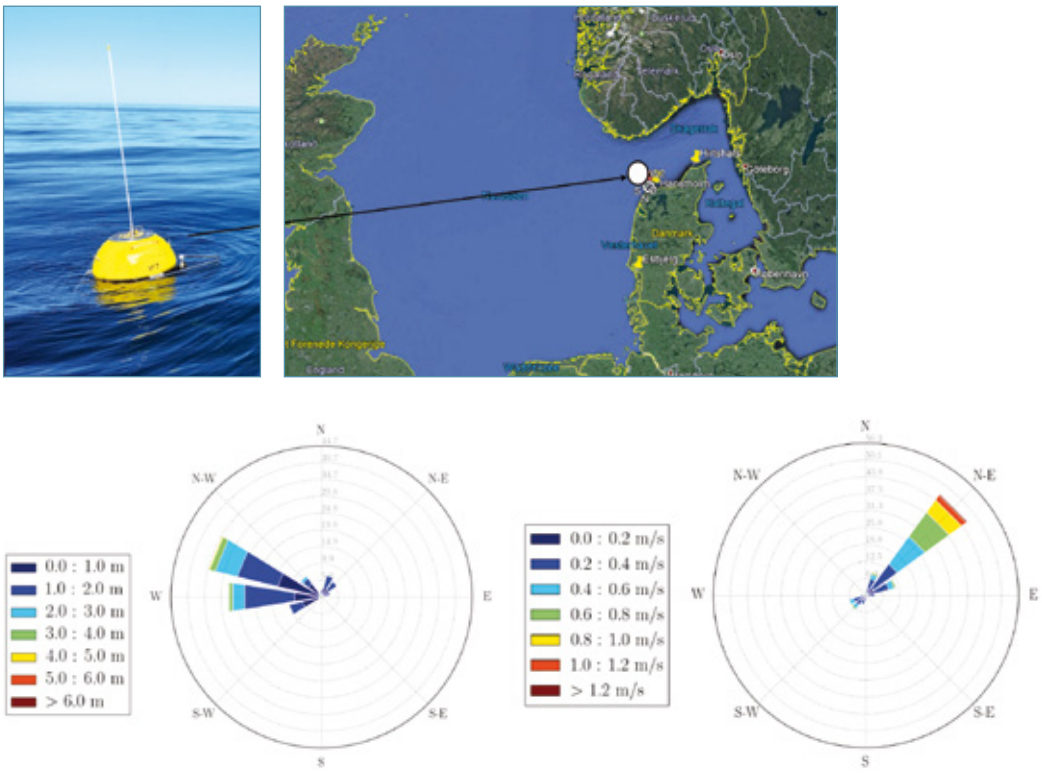
KNSwing wave energy converter investigates the use of concrete as construction material. The WEC is inspired by early UK concepts from 1978 where similar systems were investigated known as the NEL I-beam Attenuator shaped as a ship with a central buoyancy volume and along each side is placed of Oscillating Water Columns

(OWC) chambers, absorbing the wave energy converted via air-turbines. A 3-meter-long experimental model (the picture) has been tested under the MaRINET programme 2013 and 2015. The results have been compared to theory developed in co-operation with DTU and Development v. Ramboll and Kim Nielsen.

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

DanWEC is the Danish site in the North Sea for testing Wave Energy Converters. It is located close to Hanstholm Habour as shown on the image below. The water depth is between 15 – 30 meters, and the wave resource about 7 kW/m with max Hs up to 8 meters. The site is marked and equipped with two DataWell buoys measuring wave heights as well as current.

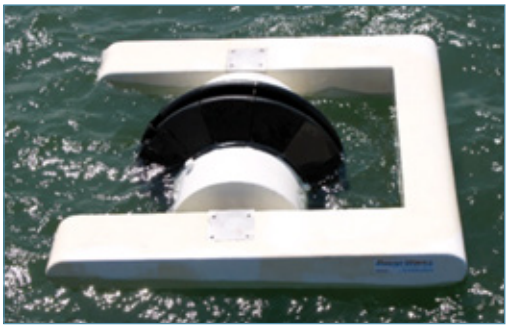


Directional measurements of waves and currents at the DanWEC Hanstholm site

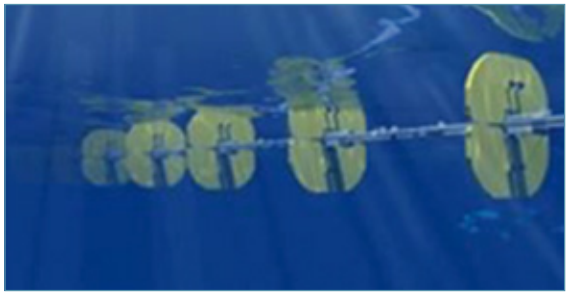
DanWEC plans to establish grid connections in order to facilitate the continued development and testing of WECs and these plans were presented to the Danish Energy Agency in November 2017, in alignment with the strategy of the Partnership for Wave Power in Denmark.

OPERATIONAL PROJECTS

Resen Waves provide small scale 300W commercial off the shelf wave energy buoys for providing electric power and real time data communication for instruments in the oceans, as a plug and play solution. The buoys can be installed in water depths up to 200 m as standard and are designed for full ocean exposure. Specials on request for bigger water depth. The technology is characterized by high efficiency, low weight and direct mechanical to electric drive with few moving parts.
Later the buoys could be scaled to 250kW to 500kW per buoy. www.ResenWaves.com



ResenWaves



WavePiston

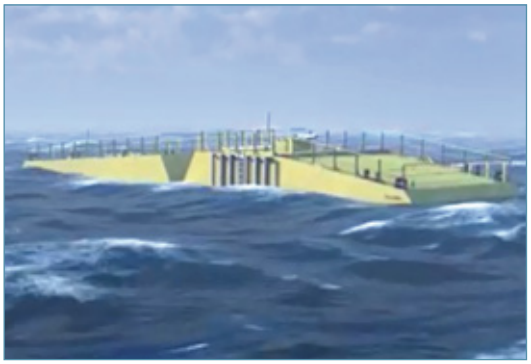
WEPTOS

WavePiston has formed a consortium with Vryhof Anchors, Fiellberg and the Technical University of Denmark, and have been testing a ½ scale prototype in the North Sea at the DanWEC test site outside Hanstholm, since 2015. The technology is a surface attenuator using the wave surge to capture the wave energy. The structure is a long steel wire rope with slack mooring in each end. On the steel wire rope many energy collectors are mounted like pearls on a string each converting the wave energy. www.wavepiston.dk

WEPTOS was tested in open sea in Lillebælt in 2017. It is a V-shaped structure that absorbs the wave energy through a line of rotors (Salter Ducks), on each arm - each transmits energy to a generator. This gives a relatively smooth energy generation, suited for known generator solutions. WEPTOS completed test in small scale in AAU 2008, as well as large scale model tests in Spain 2011 and in Edinburg 2014. http://www.weptos.com

PLANNED DEPLOYMENTS

Crestwing has been tested in the hydraulic laboratories in AAU (2008) and DHI (2010). Since 2011 Crestwing has started testing in real sea conditions in scale 1:5 in Frederikshavn. Crestwing is a "hinged raft" composed of two pontoons connected with hinges. The rotation around the hinge activates a power take-off system developed by Crestwing and placed dry in a large engine room with easy access. The plant is not visible from land even in park formation due to the low freeboard of the units. http://crestwing.dk

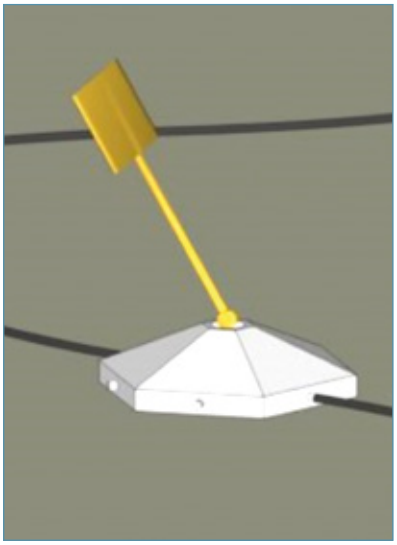


Crestwing plans to test a larger prototype in 2018

Wave Dragon was tested in Nissum Bredning in 2003 - 09. Wave Dragon is a floating device equipped with several hydro turbines. The installed power range is 1.5 to 12 MW. Wave Dragon has recently performed feasibility studies for combined wave energy and seaweed production plants at more deployment sites than the original study for the Irish Sea, https://maribe.eu, multi-purpose WD platforms equipped with environmental monitoring systems and combined WD wave-wind platforms with possible double yearly power production at deployment sites with good wind resources, leading to substantial lower cost of energy. www.wavedragon.net

Wave Dragon is investigating tests in Wales in the UK

The **Exowave** WEC element, also known as oscillating wave surge converter, extracts the kinetic energy available in the wave induced orbital water particles motion through a bottom-hinged flap. The device is intended to be installed in waters up to 40 meters depth, allowing for boats to sail above the converter itself and ensuring zero visual impact. http://exowave.com



Exowave is planning on continued testing in 2018

RELEVANT NATIONAL EVENTS

During 2017 Offshoreenergy.dk organised two WEIBs (Wave Energy Innovation Business), which typically includes a workshop followed by a B2B (Business to Business) event. The first was held in March 2017 under the premises of Ramboll, in Copenhagen, with the invited guest speaker Pablo Ruiz-Minguela, from Tecnalia/Spain, who presented the on-going EU Opera project. The second Partnership was Offshore B2B 2017, which included a united Offshore Wind to Business OWIB, Oil and Gas International Business OGIB and Wave Energy Innovation Business WEIB for two days, dedicated to networking, new knowledge and new opportunities across the offshore industry. The meeting took place in November in Esbjerg. At this meeting the new webpage for the partnership was launched https://wavepartnership.dk

EUROPEAN COMMISSION

SUPPORTING POLICIES FOR OCEAN ENERGY

The European Commission has expressed its support to ocean energy in several communications, namely the Energy Union Strategy, the European Strategic Energy Technology Plan (SET-Plan), and the Blue Growth Strategy. The aim of different policies and tools is to drive the development of ocean energy to exploit its potential to create growth and jobs in the EU.

The Energy Union Package (COM/2015/80) is the main EU energy policy, identifying five overarching dimensions for the transformation of the European energy system to make it more secure, affordable and sustainable. The development of ocean energy is framed within the Research, Innovation and Competitiveness priority; and implemented through the SET-Plan. The SET-Plan has been recognised as one of the major policy mechanisms to deliver this goal focusing on cost reduction and improving the performance of low carbon energy technologies through impactful synergetic innovation actions.

The SET-Plan builds on the Energy Union strategy and highlights the areas where participating countries align their efforts and strengthen their cooperation to support stakeholders to bring new, efficient and cost-competitive low-carbon technologies to the market faster and in a cost-competitive way. The SET-Plan identifies ten actions for research and innovation, based on an assessment of the energy system's needs and on their importance for the energy system transformation and their potential to create growth and jobs in the EU. Ocean energy activities fall under two main actions:

- Action 1: "to sustain technological leadership by developing highly performant renewable technologies and their integration in the EU's energy system"; and
- Action 2: "to reduce the cost of key technologies"

In 2016, the European Commission together with stakeholders agreed to targets for the development which were made public in the "SET Plan – Declaration of Intent on Strategic Targets in the context of an Initiative for Global Leadership in Ocean Energy".

Following the endorsement of the Declaration of Intent of Ocean Energy, in 2017 a Temporary Working Group (TWG) for Ocean Energy was setup. The mission of the TWG on ocean energy is to draft an implementation plan that will contain concrete R&I activities, and will propose relevant funding opportunities for their realisation, which are considered essential for achieving the agreed targets. The TWG is composed by 10 Member-States and relevant industrial partners, chaired by national representatives from Ireland and co-chaired by the European Technology & Innovation Platform on Ocean Energy (ETIP Ocean).

The TWG has identified 11 activities whose realisation will help reduce the cost of ocean energy technologies and meet the targets agreed in the declaration of intent. The activities address technological, financial and environmental barriers that are hindering the development and deployment of ocean energy technologies and as a consequence their cost-reduction. The Implementation plan is expected to be endorsed in 2018.

Ocean energy is also supported by the Blue Growth Strategy, the European Commission long-term strategy for the sustainable growth in the marine and maritime sector. The marine and maritime sector provides Europe with 5 million jobs and an economic impact of almost €500 billion a year. In recent years, offshore wind energy installations have changed the scenario of the maritime sector with a new industrial avenue which is already increasing employment in coastal areas.

A stable ocean energy sector is expected to contribute significantly to the growth of EU maritime regions, with estimates suggesting that the ocean energy sector could generate over 400,000 jobs by 2050 if the industrial target to deploy 100 GW of installed capacity is met.

The European Commission is currently undertaking a study to address the long-term failures of the ocean energy market with the aim to identify mechanisms to support market formation and mobilise investment into the sector. The European Commission has also launched a tender addressing the monitoring of wave and tidal energy devices in order to remove uncertainties over their potential environmental impacts. The tender is expected to start in early 2018.

MARKET INCENTIVES

The NER300 programme remains the main market incentive scheme supporting first-of-a-kind commercial scale renewable energy projects. Five ocean energy projects were awarded support through NER300 in 2013 and 2014. No new projects were announced in 2017.

PUBLIC FUNDING PROGRAMMES

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 €124 million for ocean energy R&D to 24 different projects, including feasibility studies under the Small Medium Enterprises instrument.

The European Commission currently funds 14 Projects on ocean energy, five of which were awarded in 2017 and focusing predominantly on tidal energy demonstration. Four more projects are expected to receive funds as a result of the 2017 H2020 calls. The projects are distributed in three categories: six demonstration projects (TRL>7), five research and innovation projects (TRL<7) and three coordination and support projects (addressing policy and non-technological aspects).

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 2017, Atlantis Resources Limited started the due-diligence process to obtain support through the InnovFIn EDP scheme.

REGIONAL PROGRAMMES

Further support to R&D activities is provided through the OceanERA-NET Cofund, which coordinates the support for research and development in ocean energy to facilitate collaborative solution to key challenges facing the sector. Eight countries and regions participate in the OceanERA-NET cofund project, which aims at encouraging transnational collaboration. The first list of collaborative projects is to be announced in January 2018.

At regional level the European Commission has also launched the S3P Interregional Partnership on Marine Renewable Energies. The partnership aims to pool regional resources and expertise in order to create new business opportunities and increased growth for the ocean energy. The focus of the S3P is to solve key industrial challenges, such as corrosion and manufacturing of marine energy converters.

SUPPORT TO INFRASTRUCTURES

In 2017, the European Commission has also increased its support to ocean energy through the provision of funds via H2020 for the sharing of testing facilities such as the MaRINET2, Marinerg-I, Met-Certified and the Foresea projects (the latter ones supported through the Interreg programme).

RESEARCH & DEVELOPMENT

An overview of ongoing H2020 projects is presented in Table 1, focusing on the objective of the newly announced projects and presenting the key achievements of the H2020 projects that have been operative since 2015. Highlights

include the deployment of the Penguin WEC at EMEC as part of the CEFOW project, the 1GWh mark achieved by the SR2000 floating tidal energy converter in the FloTEC project. Many projects such as TIPA, TAOIDE, PowerKite and WaveBOOST have focused on innovating the PTO of their converters. In 2018, the devices will be deployed in operational conditions to validate the efforts.

YEAR	ACRONYM	TITLE	TECHNOLOGY DEVELOPER	FOCUS	KEY ACHIEVEMENT IN 2017
2017	Octarray	Scaling up to the Normandie Hydro Open-Centre Tidal Turbine Pilot Array	OpenHydro	Scaling up OpenHydro technology for array deployment as part of the 14MW Normandy Hydro pilot array, with focus on the techno-economic viability of the project.	Among the innovations expected, the consortium aims to develop a dry test-rig for testing power-train reliability.
2017	EnFait	Enabling Future Arrays in Tidal	Nova Innovation	Designed to scale up the existing 300 kW tidal array located in Shetland with the aim of reducing cost and improving reliability.	
2017	OCCTIC	Open-Centre Tidal Turbine Industrial Capability	OpenHydro	To drive the cost of open-centre tidal turbine in par with offshore wind, through goals advancement of the turbine system design to improve performance, efficiency and reliability.	
2017	DEMOTIDE	DEMOnstration for Tidal Industry DErisking	DEME Blue energy/Atlantis	To reduce the cost of tidal energy generation and progress tidal energy to commercialisation. It aims to demonstrate a 4x1.5 MW (6MW) MCT SeaGen U tidal array at the MeygGen 1B site in Scotland.	The project has focused on innovation to reach its costs-reduction targets: • Moving from gravity base to monopole (optimal solution) • Increasing rotor diameter to reduce CAPEX
2017	InToTidal	Demonstration of Integrated Solution for offshore Tocardo Tidal power plants.	Tocardo	Demonstration of deployment solutions for tidal turbines.	Installation of the semi-floating structure with 5 turbines at EMEC expected for 2018.
2016	FLOTEC	Floating Tidal Energy Commercialisation project	ScotRenewables	Demonstration of a 2MW floating tidal energy converter, aiming to reduce the cost of the technology from €250/MWh to €200/MWh.	The SR2000 was deployed at EMEC in 2016. In 2017 it generated over 1GWh of power with capacity factors above 38%. The focus is now to implement innovations for optimisation of the tidal converter, including the integration of energy storage and the development of a manufacturing process for blades.
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, life time cost reduction and to achieve availability of 96%.	The consortium has focused predominantly on the development of WET-Gap permanent magnet generator for the PTO of their cross-flow tidal turbine.
2016	TIPA	Tidal Turbine Power Take-Off Accelerator	Nova Innovation	PTO optimisation and cost reduction of 20% of lifetime costs.	The consortium has developed a new power take-off which will be tested in Aachen in 2018, and if successful at sea. Expectation is that the 2nd generation PTO could provide cost-reduction of 20-35%.

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.	In 2017, ETIP ocean organised a number of webinars and workshop addressing the development of ocean energy and sharing experience on particular issues (wave PTO, adaptive management).
2016	ETIP OCEAN	European Technology and Innovation Platform for Ocean Energy	N/A	Provision of a unified stakeholders input for the implementation of the SET Plan actions concerning ocean energy, and expected to act as a bridge between the actions identified by the Ocean Energy Forum the SET-Plan.	The project has undertaken an analysis of marine stakeholders in Europe and is currently developing an action plan to highlight the potential of Blue Growth in different regions in Europe.
2016	MUSES	Multi-Use in European Seas	N/A	To review existing planning and consenting processes against international quality standards for maritime spatial planning (MSP) and compliance with EU Directives.	The project has undertaken an analysis of marine stakeholders in Europe and is currently developing an 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 2 years of open-sea operating data of a floating oscillating water column wave energy converter, and by doing so to remove the lack of operational data that is currently lacking for the R&D of wave energy.	Marmok device has been operational for over a year, having withstand winter storms with Hs=7.5m. A new turbine developed by Kymaner is currently being tested at the Mutriku Facility.
2016	PowerKite	PowerKite - Power Take-Off System for a Subsea Tidal Kite	Minesto	Improving the reliability of the Minesto tidal energy converter, tethered turbine.	The work of the consortium has focused primarily on improving the turbine design, PTO. A new tether design has been developed in order to reduce drag, and new control system developed.
2015	CEFOW	Clean energy from ocean waves	Wello	To decrease LCOE by improving technical solutions for multiple device system and create an efficient supply-chain to support larger wave power projects in the future. To reach its goal, the consortium plan to install an array of 3 Penguin wave energy converters.	First Penguin device installed at EMEC generating electricity. Construction and preparation for installation of a second device in 2018. Wello expecting the second device 15% more efficient than Penguin 1.
2015	WETFEET	Wave Energy Transition to Future by Evolution of Engineering and Technology	OWC Symphony	To investigate the issues of reliability, survivability and high cost of wave energy components and aim to present breakthroughs to reach commercialisation of wave energy technologies.	The project has identified a number of breakthroughs for the development of ocean energy from array configuration to materials and survivability in harsh conditions. Details of the breakthrough will be disseminated in 2018.

Table 1 Ocean Energy R&D H2020 projects awarded in 2017

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

MaRINET2 and Foresea offer developers access to testing infrastructures, with Foresea helping bridging the gap with demonstration of ocean energy converters in four European test centres. So far, the Foresea project has launched 4 calls for testing and supported 31 projects moving towards commercialisation. The Marinerg-I project has a broader vision to develop an integrated European Research Infrastructure for the development of ocean energy technologies, with the aim of increasing investors' confidence through the implementation of best practices, metrics and standards. The Met-Certified project looks instead at the development of standards and certification schemes for ocean energy technologies with the aim to increase the adoption of insurable marine energy projects.

OPERATIONAL PROJECTS AND PLANNED DEPLOYMENTS

Table 2 presents an overview of the NER 300 project announced and their status. Table 3 presents and overview of the projects that have applied for InnovFIN support and are financed or under appraisal.

COUNTRY	TECHNOLOGY	PROJECT	NER300 AWARD (million €)	PROJECT STATUS
UK	Tidal	Sound of Islay	20.65	Ongoing.
UK	Tidal	Stroma/Mey-Gen phase 1B	16.77	Ongoing. Project has reached final investment decision and is currently under construction.
FR	OTEC	Nemo	72	Ongoing. Expected installation in 2020.
PT	Wave	Swell	9.1	Ongoing. Licensing and permit obtained. Construction expected to begin 2018.
IE	Wave	WestWave	23.2	Ongoing. Public consultation and licensing initiated.

Table 2 Pre-commercial projects awarded support through NER300

COUNTRY	YEAR	PROJECT	FUNDING (million €)	STATUS
UK	2017	Stroma (Meyegn 1B)	10	Under appraisal
PT/FI	2016	WaveRoller	10 (3PT & 7FI)	Financed

Table 3 Projects supported by EIB InnovFin Energy Demo

RELEVANT EVENTS

The European Union hosted the fourth high-level Our Ocean conference in Malta on 5 and 6 October 2017. The conference aimed to inspire and empower a new generation of leaders, entrepreneurs, scientists and civil society to identify solutions and commit to actions for safe, secure, clean and sustainably managed oceans. Ocean Energy was one of the focus areas.

FRANCE

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. In application, the 10-year targets for installed capacity and consented projects for all types of energy used in electricity production will soon be updated in the governmental "Pluri-annual Energy Policy". This roadmap, to be published in 2018, will set specific objectives on the horizon 2023 and 2028. With respect to ocean energies, figures will be provided solely for tidal energy (and not for wave energy, nor for OTEC).

A new law is being discussed to favour renewable energies by simplifying their deployment. Two situations are being debated: i) to have the cost of the export cable supported by the French Transmission System Operator, for all offshore developments; ii) to streamline the legislative and legal framework by developing a so-called "permit envelope". This procedure would move most of the legal obligations (preliminary technical studies, initial environmental assessment, public debate) upstream of the actual permit issuance, thereby considerably reducing the risk for project developers as long as the technical details of the project do not diverge from the initial plan.

In parallel to this simplified consenting process, France has accelerated its Marine Spatial Planning (MSP) by launching a consultation in 2016, and pursues identification of dedicated sites for ocean energy projects. The final Strategic Seaboard Document (DSF) should be completed by early 2019.

MARKET INCENTIVES

An ongoing programme has awarded 2 demonstration pilot farms of tidal energy converters for partial support: presently, only the Normandie Hydro project is proceeding, led by the EDF-En/Naval Energies consortium at Raz Blanchard. This project benefits from an older feed-in tariff (173€/MWh) and reimbursable loans.
The industrial tidal sector is now expecting initial surveys (resource assessment, technical feasibility, environmental impact, consenting) to take place beginning in the 2nd semester of 2018, ahead of a likely call for tenders at a commercial scale, foreseen for two high-energy zones having already been identified: Raz Blanchard and the Fromveur Strait in Brittany. In this competition, a major part of the selection criteria relies on the assessed price per MWh.

PUBLIC FUNDING PROGRAMMES

In France, the general framework for RDI&D national public funding in MRE comes through the Investment for the Future Programme. Two main agencies and a public bank are involved in managing these funds through calls for tenders, namely the ADEME (Environment and Energy agency), the ANR (National Research Agency) and the public Bank of Investments (BPI France).

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

In 2017, the ANR awarded financing to 6 MRE R&D projects through the "Institute for the Energy Transition" call for tenders, in conjunction with France Energies Marines. These public-private collaborative projects tackle technological bottlenecks and environmental issues. In all, and over the period 2015-2017, the government awarded 10 M€ of R&D funding through this program.

One of the activities of BPI France is to buy shares in SMEs. To this end, in 2017, it was among the investors that increased by 3,7 M€ Eel Energy's capital to support its tidal energy technology development.

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

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

RESEARCH & DEVELOPMENT

Call for projects: Marine Renewable Energies Institute for the Energy Transition 2015
France Energies Marines, in cooperation with the National Research Agency, launched 21 successfully financed collaborative MRE R&D projects in the period 2015-2017. Below is a brief listing of the treated subjects in the projects started in 2017.

DiME - Dimensioning and met ocean: modelling and observations of extreme sea states for MRE
ABIOP- Accounting for biofouling through established protocols of quantification
MHM-EMR - In service health monitoring of MRE moorings to anticipate failures
POLYAMOOR - Durable and flexible polyamide moorings for MRE
SOLCYP+ - Monopile design for fixed offshore wind turbines, calculations for installation procedures
STHYF - Seafloor cable stability and hydrodynamics in strong tidal currents
GEOBIRD - Development of an innovative geolocation tag for seabirds
SPECIES - Submarine power cable interactions with environment

MaRINET2
Ifremer, Ecole Centrale de Nantes (ECN) and Oceanides are involved in the MaRINET2 project (http://www.marinet2.eu/), offering possibilities for technology developers to test their devices in recognized research facilities, including real sea test conditions. Under MaRINET2, calls are open to give developers the chance to access testing facilities in Europe free of charge. In the first call this year, 48 proposals were received from 21 countries. Support of €1.3 million has been awarded to 34 projects for free of charge access to testing facilities. The second call for proposals will open on the 15th of January, 2018.

Ifremer and ECN have joined their efforts to set-up a grouping of scientific interest (GIS), named THeoRem, in order to create a National Research Infrastructure related to hydrodynamic testing facilities. The GIS was officially signed on 13 March 2017, between ECN and Ifremer bringing together a unique set of hydrodynamics facilities (3 test tanks and the SEM-REV open sea test site for ECN; 2 test tanks and the Saint Anne du Portzic test site for Ifremer). A dedicated website will be set-up early 2018 (www.theorem-infrastructure.org)

EEL GEN project
The project, led by Eel Energy in partnership with Hutchinson and Ifremer, aims at developing a 1 MW tidal energy convertor using an undulating membrane. After having successfully performed a range of scaled model tank tests (at 1/20 and 1/6 scales), numerical modelling and material proofing, a prototype has been tested in Brest Harbour. The

towed tests have been performed using the Iroise Mer - TSM Vessel *Penzer*. Results of the tests will feed the on-going development of the full-scale prototype.

Set-up of the Eel Energy membrane for the tests in the Brest harbour – Copyright Ifremer

MET-CERTIFIED

MET-CERTIFIED aims to increase the adoption of insurable and therefore bankable marine energy projects in the European Interreg 2 Seas area (Southern North Sea and the Channel) through the development of internationally recognised standards and certification schemes in the sector. The project will be of big interest to many stakeholders involved in certification, from banks and insurers to consenting authorities, end-users, test facilities and classification bureaus.

The first experimental campaign (10 days of trials) has been carried out in the Ifremer wave and current circulating tank on a generic three-bladed horizontal axis tidal turbine at a scale of 1:20, for different flow speeds and turbulence intensity levels. The experimental set-up and protocols take into account the actual best practices and guidelines, in absence of standard protocols.

The publicized behaviour and performance (EWTEC 2017, Cork: *Testing of marine energy technologies against international standards. Where do we stand ?*, G. Germain & al.) allow to highlight some important points and procedures to focus on if the results from tank tests are to be exploited with confidence.

ICE

9 organisations from France and UK have partnered to tackle the challenge of energy vulnerability in areas located at the end of the distribution network and reliant on fossil fuels: the ICE project (2017 – 2020), "Intelligent Community Energy", is dedicated to improving, developing and promoting new, smart solutions for energy production, storage and consumption for an island or remote community. This project will be funded by the France (Channel) England Programme through the European Regional Development Fund (ERDF). In this framework, the D10 Sabella tidal turbine will carry on its demonstration installation at Ushant, an island at the western end of Britanny.

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

France has several test centres fully equipped and grid connected, where projects have been and are about to be tested: Floatgen, a nearly assembled offshore wind turbine had its mooring installed this summer at **SEM-REV** on the west coast, offshore Le Croisic, ahead of the actual shore connexion. In addition, 3 wave energy demonstrators are planned

to be tested next year. At **SENNEOH**, a tidal test site in the Gironde Estuary in the city of Bordeaux, the first tests of the ¼-scale HydroQuest marine turbine will be hosted. Future plans include testing their technology at full scale next year at **Paimpol Bréhat**, a tidal test site operated by EDF in North Brittany. **BREST Saint-Anne** is a new test site for scaled projects where GEPS Techno thoroughly tested its multi-energy platform (PH4S pilot project integrating wave, wind, tidal and solar energy conversion systems) and where EOLINK plans to test a 1/10-scale floating wind turbine in 2018.

GEPS Techno PH4S prototype at Saint-Anne test site – Copyright Ifremer

PLANNED DEPLOYMENTS

Regarding the deployment of the Sabella tidal turbine at Ushant, and in addition to the ICE allowing the D10 demonstration to be continued, the PHARES project aims at implementing on this unconnected island a fully renewable production of electricity based on 2 Sabella D12 turbines (12 m diameter for a 2 MW capacity), 1 MW of PV, 1.5 MW from 1 onshore wind turbine and 2 MWh of battery storage.

The Normandie Hydro project plans to install a capacity of 14 MW with 7 tidal turbines operational in 2021. At a short distance in Cherbourg, Naval Energies launched in July of 2017, the construction of a plant dedicated to the assembly of 25 turbines/year.

Guinard Energies has proceeded to several operational tests at sea in Brest (Brittany) in 2017, with a 3.5 kW hydrokinetic device P66 (66cm diameter of the funnelled turbine) combined with solar panels and batteries. The complete power conversion chain has been tested and validated. Those first conclusive tests will be followed by a demonstration project in February 2018 on the Ria d'Etel site in Brittany. The system includes a complete off-grid scheme with solar panels and batteries, in order to confirm the power conversion flexibility and efficiency in harsh conditions. This demonstration will be followed by several P66 installation on- and off-grid through Brittany, French and overseas during the year 2018. The pilot site of Ria d'Etel will also be used for P400 (4 m diameter) demonstration.

RELEVANT NATIONAL EVENTS

Seanergy

The second annual international convention on marine renewable energies took place in Le Havre on 22-23 March 2017. In total, 3500 participants and 230 exhibitors from 20 countries participated in two days of presentations, seminars, meetings and expositions. This was also the occasion for the professionals to meet at a plenary meeting, one month ahead of the presidential election, with representatives of all the main candidates to hear their views on MRE. In 2018, this national event will merge with the international congress ICOE which will take place in Cherbourg, also in Normandy, on 12-14 April. First presented at Seanergy, an assessment of marine renewable energy related jobs (in French) has been published[1] this year: a total of 2086 direct jobs have been identified in this study, in the field of marine energies, in France (75% in relation to offshore wind and 25% in ocean energy).

MRE Masters programme

The engineering school ENSTA Bretagne continues to offer a specialized master's degree in marine renewable energies. Designed to complement a degree in engineering or a master's in mechanical engineering, the MRE Master's programme allows the acquisition of dual skills in engineering and MREs.

1. http://www.merenergies.fr/documents/OEM-Rapport.pdf

GERMANY

OCEAN ENERGY POLICY

The expansion of renewable energy is one of the central pillars in Germany's energy transition. In light of an increasing scarcity of resources, the aim is to become less dependent on fossil fuels and to make Germany's electricity supply more climate-friendly. The growing significance of renewable energy sources in the power sector is largely a result of the Renewable Energy Sources Act (EEG). Since the adoption of the Renewable Energy Sources Act, the share of gross power consumption of renewable energies grew from about 6% in 2000 to 36.1% in 2017 according to preliminary data. By 2025, 40-45 % of electricity consumed in Germany is to be derived from renewables. Wind and solar energy are the most important forms of renewables, but biomass and hydropower are also valuable building blocks of the German energy system.

With the 2017 revision of the Renewable Energy Sources Act funding rates for renewable electricity are no longer fixed by the government, but are determined via a market-based auction scheme – a fundamental change in funding Germany's renewable energies. These competitive biddings schemes are already showing a cost-cutting effect. E.g. average funding rates for onshore wind energy installation auctions have dropped by 25% between May 2016 and August 2017 (source: Federal Ministry for Economic Affairs and Energy). Excluded from the bidding schemes are hydro power plants (including wave, tidal range and currents and salinity gradient), landfill and sewage gas and geothermal plants. For those, fixed feed in tariffs continue to be applied which e.g. in the case of hydropower and ocean energy systems range from 12.4 € Cent/kWh for systems below 500 kW to 3.47 Cents/kWh for plants above 50 MW.

While the recent production figures indicate, that the energy transition is making good progress in terms of increasing renewables and phasing out nuclear energy, greenhouse gas emissions stagnated at the same level for the third year in a row, mainly due to increased emissions in the transport, building and industrial sectors. Extrapolating the current trend, Germany will cut its emissions by only 30 % compared with 1990 levels instead of 40 % as planned (Source: Dr Patrick Graichen, Director of Agora Energiewende).

The current 6th energy research programme of the Federal Ministry for Economic Affairs and Energy as published in 2014 continues to fund R&D projects with regard to ocean energy technologies. Up to now, around 12 technology projects related to the development of components and concepts for tidal turbines and wave energy components have been funded. A consultation process for the follow up 7th energy research programme started end of 2016. The new programme is expected to be released in summer 2018.

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.

Within the joint project "TidalPower", running until June 2018, a consortium consisting of SCHOTTEL HYDRO, Fraunhofer IEE (former IWES Kassel), the Institute for Fluid- and Thermodynamics (IFT) at the University of Siegen, Hamburg Ship Model Basin (HSVA) and Potsdam Model Basin (SVA) aims at facilitating the development of the "TRITON" platform, a 2.5 MW semi-submersible platform carrying 40 SCHOTTEL HYDRO tidal turbines. In late 2017, SCHOTTEL HYDRO announced the discontinuation of the "TRITON" platform and gave up on plans to deploy a prototype at a berth at the FORCE tidal research centre in the Bay of Fundy, Canada. Now, smaller floating platforms comparable to Sustainable Marine Energy's (SME) 280 kW "PLAT-I" platform are to be used instead. Separated from the discontinu-

ation of the “TRITON”, SCHOTTEL HYDRO continues to provide their “SIT” tidal turbines and custom power take-off systems to third party tidal developers like SME, QED Naval and Minesto.

The NEMOS GmbH together with Uni Duisburg Essen, the Development Centre for Ship Technology and Transport Systems, Schaeffler Technologies AG and LIROS GmbH, continued the development of its wave energy conversion technology in the joint project “Design, Manufacturing, Installation and Commissioning of NEMOS Wave Power Plant Model at 1:1 Scale”. The project runs until July 2019 and is supposed to deliver a full-scale WEC prototype. Construction started in February at a Belgian shipyard, the installation in the North Sea near the Port of Ostend was permitted in June 2017. In-situ soil investigation were successfully performed in September. (source: www.nemos.org).

Wave power developer SINN Power GmbH started the project “Testing of a Modular Concept for the Generation of Grid Conform Electricity from Irregular Ocean Waves in a Generator Array” in August 2017. The project runs until July 2019 and is supposed to deliver four additional WEC modules to the existing test site at the port of Heraklion, Greece. Furthermore, a floating WEC grid of 21 modules is to be installed at an organic shrimp farm on the island of São Vicente, Cape Verde, in 2018 (source: www.sinnpower.com).

REAC Energy GmbH from Bavaria, southern Germany, tested a single unit of their modular tidal turbine technology in Orkney waters in October. The “StreamCube” is a vertical axis Savonius turbine with self-adjusting rotor geometry, rated at 6 kW (source: http://www.reac-energy.com).

The project STENSEA – “Stored Energy in the Sea” delivered and tested a 1:10 scale model of a concrete sphere based pumped storage in Bodensee lake, Germany. The project finished successfully in March under participation of Fraunhofer IEE and HOCHTIEF Solutions AG. A successor project testing a larger sphere offshore is currently being developed for funding.

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 GI-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.

“Stored Energy in the Sea” - 1:10 scale model tested in Lake Constance, Germany

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, feasibility and technical aspects of ocean energy related proposals as and when required.

PUBLIC FUNDING PROGRAMMES

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

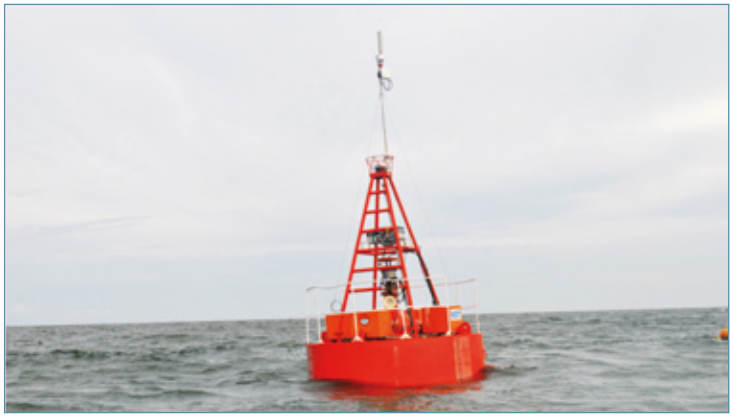
The Ministry of New and Renewable Energy, under the Government of India, has a mandate to increase the share of renewable energy in meeting India's power demand. This Ministry also covers ocean energy as a part of the new technologies development programme and attempts to fund ocean energy devices which show promise.

RESEARCH & DEVELOPMENT

The National Institute of Ocean Technology, under the Ministry of Earth Sciences, carries out research and development activities related to ocean energy. A few academic institutions like the Indian Institute of Technology Madras and the Indian Institute of Technology Bombay are working on wave energy.

WAVE ENERGY

As part of the efforts to install a floating wave powered device to power loads or to meet the lighting requirements of coastal areas of remote locations, NIOT has been working on Oscillating Water Column (OWC) principle based wave energy devices such as Backward Bent Ducted Buoy (BBDB) over the last few years. Recently, NIOT has developed and tested a wave powered navigational buoy off the coast of Chennai. This buoy is sized for meeting the power requirements of a beacon lamp and will be used to mark navigational channels in ports and harbours. The total cost of this indigenously developed buoy is less than those available in the market. This buoy was formally launched on 13 November 2017 on the sidelines of the IEA-OES Executive Committee meeting held in Chennai.



Testing of NIOT's wave powered navigational buoy near Kamarajar Port, Chennai

An oscillating air flow test rig for testing wave energy turbines has been set up at the Indian Institute of Technology Madras with funding from NIOT. The rig is equipped with state of the art instrumentation and data logging system and can be used for turbines with maximum capacity of 1 kW.

ENERGY FROM OCEAN THERMAL GRADIENT

As a part of the activities related to Ocean Thermal Energy Conversion (OTEC), NIOT has set up a state of the art laboratory for carrying out studies on various components of OTEC and Low Temperature Thermal Desalination (LTTD). This facility is located inside NIOT campus in Chennai. The test setup is equipped with seawater pumping and storage system with capacity of 60 m3. Requisite surface sea and deep sea temperatures are maintained using oil fired heater and chiller. Studies on LTTD, open cycle OTEC and closed cycle OTEC can be carried out in this test setup along with combinations of them. The process equipment for this setup has been indigenously developed, and that includes a turbine for closed cycle operating with the R134a fluid and a turbine for open cycle operating with flashed steam. The facility was inaugurated on 13 November 2017 on the sidelines of the IEA-OES Executive Committee meeting held in Chennai.

OTEC Desalination Laboratory at NIOT, India

TECHNOLOGY DEMONSTRATION

PLANNED DEPLOYMENTS

NIOT is building a few more prototypes of indigenously developed wave powered navigational buoy. These prototypes are planned to be deployed at different ports on the East Coast of India. These buoys will have beacon lamp and basic instruments to measure met-ocean parameters. The deployment is expected to be completed in mid-2018.

Also, it is planned to take up an Oscillating Water Column based wave energy project of 100 kW. The project will commence after the necessary clearances are obtained.

A recent survey carried out by NIOT at a few places on the Andaman and Nicobar Islands indicates that there is a good potential for hydrokinetic turbine deployment on the Andaman Islands. Based on these measurements, NIOT's ocean current turbine module with 1 kW average capacity is being readied for deployment in 2018 at a suitable location.

The preparatory work for OTEC powered Desalination Plant (at Kavaratti in the Union Territory of Lakshadweep), like surveys and legislative clearances, is about to be completed. The plant site has been identified and Request for Proposals (RFPs) is under preparation.

OTHER RELEVANT NATIONAL ACTIVITIES

As a step towards formulating a roadmap, NIOT organised a brainstorming session on Ocean Energy Development in India on 27 March 2017. The participation in this session was by invitation to key stakeholders from industry, academia, companies in public sector and government departments. It was recommended to install an intermediate scale wave energy converter on one of the islands, to carry out resource assessment for a few target locations, to work on inter-ministerial involvement in large OTEC projects and to explore hybrid energy production via multipurpose floating systems.

India hosted the 33 meeting of the Executive Committee of Ocean Energy Systems in November 2017 in Chennai. On the sidelines of this meeting, NIOT organised a workshop on ocean energy development on 13 November 2017 in Chennai with participants from the Department of Science and Technology, the Ministry of New and Renewable Energy, the Indian Institute of Technology, the Ministry of Earth Sciences, etc.

Workshop on Harnessing Energy from Ocean - A Global Scenario on 13 November 2017

IRELAND

SUPPORTING POLICIES FOR OCEAN ENERGY

Ireland remains open for business and is actively committed to harnessing its abundant wave, tidal and offshore wind energy resources while developing an indigenous ocean energy industry in the process. The publication of the Offshore Renewable Energy Development Plan in 2014, and its ongoing implementation through the Offshore Renewable Energy Steering Group, has had the benefit of facilitating a genuinely collaborative environment in this area. This plan was reviewed in 2017 by relevant stakeholders at government and industry level to ascertain progress on actions; to ensure continued focus on appropriate priority areas and to realign the plan with any changes in political or technical landscapes.

The initial outcome of the review suggests that all relevant Agencies and Government Departments within Ireland remain committed to supporting this burgeoning sector and offering one single gateway for information as well as access to particular supports for the development of the ocean energy industry in Ireland. The importance of supporting technology developers while also investing in academic research has been well-recognised, and the past year has seen tangible progress in both areas with some flagship projects already underway.

NATIONAL STRATEGY

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 highlights the potential opportunities for the country in relation to marine energy at low, medium and high levels of development, as derived from the findings of the Strategic Environmental Assessment of the plan carried out prior to publication. The 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.

The implementation of the OREDP is led by the Department of Communications Climate Action and Environment (DCCAE) and the Offshore Renewable Energy Steering Group (ORESG) is actively overseeing its implementation. The Steering Group consists of the main Government departments and agencies with roles and responsibilities that relate to energy and the marine environment, developers and broader interest and user groups when necessary.

The work of the ORESG, and hence the implementation of the OREDP, is organised according to three work-streams: Environment, Infrastructure and Job Creation. The Job Creation working group has responsibility across several actions, including identifying additional exchequer support requirements, supply chain development and communicating the message that 'Ireland is Open for Business'. Under the Environment work-stream the Group ensures the needs of the marine energy industry are reflected in the on-going reform of the foreshore and marine consenting process. The actions deriving from the SEA and AA of the OREDP will also be taken forward under this work-stream to ensure that future marine energy development takes place in an environmentally sustainable manner. The Infrastructure working group concentrates on supporting and delivering objectives of other policies such as the National Ports Policy and Grid 25 so as to expedite integrated infrastructure development which will facilitate the offshore renewable energy sector. This plan was reviewed in 2017 by relevant stakeholders at government and industry level to ascertain progress on actions; to ensure continued focus on appropriate priority areas and to realign the plan with any changes in political or technical landscapes. The review of the OREDP was subject to a full public consultation in

November/December 2017. The final report of the review is not yet published, but it is anticipated in summer 2018. Initial indications from the review process are that currently the OREDP is progressing well but that in some areas additional focus is required.

IRELAND'S TRANSITION TO A LOW CARBON ENERGY FUTURE 2015 - 2030

The White Paper 'Ireland's Transition to a Low Carbon Energy Future 2015-2030', published by DCENR in 2015, is a complete update on Ireland's wider energy policy. This paper sets out a framework to guide policy and the actions that Government intends to take in the energy sector from now up to 2030, while taking European and International climate change objectives and agreements, as well as Irish social, economic and employment priorities, into account. The White Paper anticipates that ocean energy will play a part in Ireland's energy transition in the medium to long term and reiterates the OREDP's status as the guiding framework for developing the sector.

REGULATORY FRAMEWORK

Currently, proposed ocean energy developments require a Foreshore Licence (for non-exclusive and temporary uses) and/or a Foreshore Lease (exclusive and permanent uses) granted by the Minister of Housing, Planning, Community & Local Government. Deployment of an ocean energy device may require an Environmental Impact Assessment (EIA) depending on its nature, size and location, in accordance with European Union (EU) law and national legislation. Similarly where a development is located in or near a site designated for nature conservation purposes, under the EU Habitats Directive, an Appropriate Assessment (AA) may also be required. If a development comprises onshore works (terrestrial) planning permission from the adjoining planning authority (County Council) will be required. A new Maritime Area and Foreshore (Amendment) Bill is expected to be enacted which will align the foreshore consent system with the planning system in order to streamline the EIA and AA processes for projects.

2017 saw the publication of guidance on Environmental Impact Assessment Reports (EIAR) and Natura Impact Statements (NIS) for offshore renewable energy projects ensuring best practice is adopted in order to develop the industry in an environmentally friendly manner. Further guidance is anticipated on Environmental Monitoring and baseline data collection in the coming months.

MARKET INCENTIVES

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

While the primary objective of the new RESS is to incentivise the introduction of sufficient renewable generation to deliver national and EU wide renewable energy and decarbonisation targets, there are other energy policy objectives. The objectives include: the broadening and diversifying of the renewable technology mix, enhancing security of energy supply, promoting economic development, and supporting community and citizen participation in the transition to a low carbon economy. These objectives must be met, while simultaneously delivering value for money for the consumer. Providing pathways for increased community participation is also considered be a cornerstone of the new scheme, delivering on Energy White Paper commitments.

The proposed new RESS has been designed with the primary policy objective of delivering sufficient renewable electricity to meet Ireland's contribution to the EU wide renewable energy targets, out to 2030. The proposed design also meets Ireland's three energy pillars of Competitiveness, Security of Supply and Sustainability, while simultaneously addressing other stated government ambitions. The Floating Feed In Premium (FIP) performed best against the assessment criteria and was selected as the primary financial support mechanism for the new RESS. This support will be allocated through auctions, with potential exceptions for small-scale generation or emerging technologies.
A separate Community Category in also included within the RESS to support community-led projects. Several proposals regarding the features of a community scheme within the new RESS consultation were suggested. These proposals included: projects supported under the RESS must offer the community an opportunity to invest, a floating feed-in-premium (FIP) should be made available for smaller community projects (<6MW wind, <1MW other technologies), and development grants should be made available to suitable community-led projects. The report also explored

several means of enabling communities to make their investments, including tax incentives, green bonds, facilitating crowd funding and offering investment soft loans. No recommendation is made regarding supporting these options but further analysis of these measures is proposed to understand their suitability. It is also proposed that pathways for micro-generation be developed outside of, but in conjunction with, the main RESS.

The public consultation generated thousands of responses and it is anticipated that it will take a number of months in 2018 to review and integrate these into the plan. Feedback on the plan and proposed direction is anticipated once this process is completed.

PUBLIC FUNDING PROGRAMMES

SEAI Prototype Development Fund

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

- Projects to develop and test wave and tidal energy capture devices, systems and sites.
- Independent monitoring of projects/technologies.
- Industry-led R&D aimed at the integration of ocean energy into the electricity market and the national electricity grid (and network).
- Data monitoring, forecasting, communications and control of ocean energy systems.

The programme launched in 2009 and to date has supported over 100 projects with +€14m grant funding.

Pre-Commercial Technology Fund

In order to meet the changing requirements of the ocean energy sector, and particularly ocean energy technology developers, SEAI is investigating funding mechanisms to help accelerate the commercialisation of wave and tidal energy devices and components. In 2016 the Marine Renewables Industry Association (MRIA) published its report '*Funding the Development of the Ocean Energy Industry in Ireland*', with the support of SEAI. This report recommends the establishment of a 'Pre-Commercial Technology Fund (PCTF) to close the 'funding gap' for device and sub-system developers at TRL3+ and to complement the current Prototype Development Fund'. SEAI are progressing these recommendations and have sought further advice from appropriate consultants and stakeholders on how to develop a scheme appropriate to the Irish market and Industry.

OCEANERA-NET

The ERA-NET scheme is an innovative component of the European Union's Framework Programme, which supports co-operation of national/regional research funding programmes to strengthen the European Research Area (ERA). OCEANERA-NET (http://www.oceaneranet.eu), aims 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 is a participant in the OCEANERA-NET, along with 16 funding Agencies from 9 European countries. Six projects with nine Irish partners were approved in the two OCEANERA-NET joint calls.

Ocean Energy ERA-NET Cofund

The Ocean Energy ERA-NET Cofund (OCEANERA-NET COFUND) is a five-year action that secured support through the European Union's Horizon 2020 Programme for Research and Innovation in 2016. This new programme will build on the work of OCEANERA-NET and with an increased budget and financial support from the EU Commission, the COFUND programme focuses on collaborative projects that demonstrate and validate innovative technologies for ocean energy. OCEANERA-NET COFUND aims to support transnational, collaborative research and development projects in ocean energy through joint calls and carry out other joint activities which will enhance the coordination of public research and innovation programmes and improve the exploitation of results of the projects funded. The first joint call was launched in 2017 and was open to applicants from three European countries (Ireland, Spain, Sweden) and four regions (Brittany, Pays de la Loire, the Basque Country, and Scotland). Five projects with seven Irish partners were approved in this COFUND joint call.

RESEARCH & DEVELOPMENT

Marine Renewable Energy Ireland (MaREI)

MaREI is a centre of excellence for marine renewable energy, supported by Science Foundation Ireland (SFI). The Centre combines the expertise of a wide range of research groups and industry partners, with the shared mission of solving the main scientific, technical and socio-economic challenges across the marine and renewable energy spaces. In addition to facilitating fundamental research activities, the MaREI research programme is closely aligned to the requirements of its industry partners and the marine and renewable energy sectors as a whole, providing innovative solutions that reduce the time to market, and reduce costs to a competitive level.

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

By the end of 2017, MaREI had over 200 researchers in place working on a variety of fundamental and applied research projects across its six academic partner institutions. These included targeted projects with 45 industry partners, comprising a range of SMEs and MNCs across the marine and renewable energy spaces. The contract with SFI for funding for the current centre is due for renewal in 2019. MaREI has sought additional funding to expand their research brief and the Universities involved in the project. Results of this application will be confirmed in 2018.

Lir National Ocean Test Facility

The Lir National Ocean Test Facility (NOTF) is a world-class center 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 new 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. The upgraded facilities will provide support to developers in taking their first steps in testing and developing their devices and is a vital component of Irelands test infrastructure.

EU Projects

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

- The H2020 INFRARIA 2016-2017 MaRINET2 project will provide and co-ordinate free access to ocean energy developers to test infrastructure throughout Europe. MaRINET2 will build upon the previously successful MaRINET programme. UCC are project co-ordinators. Facilities at NUI Galway and the University of Limerick are also included, as well as the Galway Bay Marine and Renewable Energy Test Site.
- The H2020 INFRADEV 2016-2017 Marinerg-i project, led by UCC, aims to unite Europe's leading renewable energy research organisations to become the leading international distributed infrastructure. Its integrated nature and co-ordinated approach will accelerate the research development and deployment of offshore wind, wave, tidal and combined energy technologies and help maintain Europe as a global leader in this sector.

- The H2020 TAOIDE proposal is to develop a fully-integrated generator to grid energy delivery system with high reliability and availability, suitable for use in multiple architectures of marine renewable energy systems. This work will provide the basis for development of a power production system certified for use in marine renewable energy applications – a system designed for the specific environments and regulations of the European Union market, utilising skills, expertise and capabilities of European partners. The Irish partners in this project are ORPC Ireland, UCC, and Letterkenny Institute of Technology.
- The H2020 OPERA (Open Sea Operating Experience to Reduce Wave Energy Cost): The primary objective of OPERA is to gather open-sea operating experience to reduce the cost of wave energy. UCC/MaREI are a contributing partner
- The H2020 FloTEC Project (Floating Tidal Energy Commercialisation): The FloTEC project will demonstrate the potential for floating tidal stream turbines to provide low-cost, high-value energy to the European grid mix. The project will entail the construction of a turbine device that will be deployed alongside an existing floating tidal array which will serve as a demonstration platform for commercially viable tidal stream energy. Irish partners include UCC/MaREI and Eirecomposites.
- INTERREG NWE FORESEA project (Funding Ocean Renewable Energy through Strategic European Action). This project aims to help bring ocean energy technologies to market by providing access to North-West Europe's world-leading network of test centres. Through the project, the performance of innovative ocean renewable energy technologies will be demonstrated in real sea conditions, helping to leverage the investment needed to take these new products to market. Irish Partners are Smartbay Ireland and access to the Galway Bay test site can be achieved through this mechanism.
- INTERREG BRYDEN PHD Programme. This programme offers fully funded PhD Studentships in Marine renewable energy and Bio-energy in the following institutions - Queen's University Belfast, University of the Highlands and Islands, Letterkenny Institute of Technology, Ulster University, Agri-Food & Biosciences Institute, Donegal County Council and Dumfries and Galloway Council. Using a Doctoral Training Centre model, the BRYDEN CENTRE project will recruit 34 PhD students and 6 PDRAs; each of whom will work with industry to produce industrially relevant research with the potential for commercial exploitation and resulting economic growth within the region. Final output will be 68 peer reviewed journal and conference publications with cross border authorship. Letterkenny IT are the Irish Partners in this project.

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

Ireland has a unique ladder of development and test site infrastructure, allowing developers to move from laboratory test facilities at the Lir National Ocean Test facility in Cork, to a quarter scale test bed in Galway Bay and to a full test facility at the Atlantic Marine Energy Test Site (AMETS) near Belmullet, Co. Mayo. Significant steps were taken to further develop these facilities in 2017.

Galway Bay Marine and Renewable Energy Test Site

Ireland's ¼ scale ocean energy test site is located within the Galway Bay Marine and Renewable Energy Test Site and is situated 1.5 km offshore in water depths ranging from 20 m – 23 m. The site has provided test and validation facilities for a number of wave energy devices and components to date. The SeaPower platform, a quarter-scaled wave energy converter, was successfully deployed to the site between November 2016 and March 2017. The scaled wave energy converter produced both energy and survivability data during that time.

November 2017 saw the successful testing of the Acoustic Array System, design for deployment at the test site. This equipment was produced through the Acoustic Monitoring project, a multi-disciplinary research and development initiative led by SEAI and supported by the Marine Institute and running since 2012. The Acoustic Array System comprises of multiple sensors in an array and it is intended to be placed in the vicinity of a wave energy converter to quantify the noise emitted by the device.

Activity at the site was somewhat limited in 2017 due to unforeseen delays in granting an updated foreshore lease for the site. However on December 19th the Department of Housing, Planning and Local Government announced that the foreshore lease for Galway Bay Marine and Renewable Energy Test Site had been renewed. Under the conditions of the new lease, three marine renewable energy test devices can be deployed at the test site for a duration of up to 18 months, with the exception of floating wind devices which may only be deployed for 12 months. As a condition of the lease the Marine Institute will appoint a community engagement officer to liaise with the local community regarding on-going operations at the site and will provide an information centre in the vicinity of the test site.

Atlantic Marine Energy Test Site (AMETS)

SEAI is developing the Atlantic Marine Energy Test Site (AMETS) to facilitate the testing of full-scale ocean energy converters in an open ocean environment. It is located off Annagh Head, west of Belmullet in County Mayo, and will be connected to the national grid. AMETS will provide for full-scale test opportunities in extreme Atlantic conditions and is intended as the ultimate test site for pre-commercial stage devices.

AMETS will be focused on the development of wave energy convertors and will provide two separate test locations, at 50 m and 100 m depths to allow for a range of devices to be tested. The site will be grid connected and will allow for 10 MW of production.

A foreshore lease for the test site has been awarded after going through the necessary consenting and environmental monitoring processes. Planning permission for onshore aspects of the site have also been secured and grid connection work has commenced. Currently preparation is being made for a substation build, as well as development of multiple cable routes connecting to both the testing berths.

Belmullet coastline, Co. Mayo

PLANNED DEPLOYMENTS

GKinetic Ltd. is a Co. Limerick based developer of a submerged tidal energy device composing of twin, multi-bladed, vertical axis turbines mounted either side of a tear drop shaped 'bluff body' that will be moored to the seabed. The concept has undergone staged development, in line with industry best practice. Previous testing has been undertaken at NUI Galway, the IFREMER flow tank facility at Boulonge-Dur-Mer in France and numerical modelling for design optimisation. GKinetic conducted a series towing tests of a 1/10th scale version of the turbine system in Limerick Docks in late 2015 in order to understand and assess the performance of the technology, and will re-deploy in 2017

for more advanced testing. In August 2017, GKinetic carried out tests on an improved prototype in the Limerick docks for a period of six weeks. The devices newly improved PTO system and blade performance were monitored with important data gathered.

GKinetics 1:10 scale model being tested at Limerick Docks

SeaPower Ltd. is a Co. Sligo based R&D and engineering company who have developed a wave attenuator device called the SeaPower Platform. Since its conception in 2008, SeaPower have progressed from numerical modelling and design, to tank testing in Cork, and now to the open sea Galway Bay Marine and Renewable Energy Test Site. The company have received support from the SEAI Prototype Development Fund throughout its development, and the current project saw the device deployed to the quarter-scaled Galway Bay test site from November 2016 until March 2017. Since deployment, the company have been continually receiving wave energy data and assessing survivability in open sea winter conditions. With the renewal of the lease for the Galway Bay Marine and Renewable Energy Test Site testing will continue in 2018.

SeaPower Platform at Foynes Port, Co. Limerick in 2016 (Left). SeaPower Platform being towed to the Galway Bay test site in 2016 (Rigth).

OE Bouy plan to test a half scale model in US Navy WETS facility in Hawaii in September 2018. 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 the design of the technology and planning for transport and access to the site. It is stage/phase 4 of the Development & Evaluation Protocol for Ocean Energy technology, the prior stages having been completed with financial assistance from the Marine Institute, Enterprise Ireland, EU funding and SEAI. The prior stage included a number of deployments at the Galway Bay Quarter Scale test site – during which the device accumulated over 24,000 hours of open water testing.

Ocean Energy Buoy in Galway Bay Marine Renewable Energy Test Site

ESB's **WestWave** project aims to develop a 5 MW wave energy project off the west coast of Ireland, at a site near Killard, Co. Clare. The current phase of the project is developing the foundations for this project to allow the capital investment and procurement phase. Ongoing activity includes to securing the required permits, conducting site investigations, including detailed wave measurements, and to developing the design and functional specification of the project. It is anticipated that applications for the site's Foreshore Lease and onshore planning permission will be lodged in 2018.

OTHER RELEVANT NATIONAL ACTIVITIES

Ocean Power Innovation Network

The Ocean Power Innovation Network (OPIN) is a collaborative industry network that has been developed by agencies in Ireland, Northern Ireland and Scotland. The network's mission is to advance innovation in the sector by learning from experts in other industries, to push the boundaries of what's possible in ocean energy and progress innovative ocean projects in a coordinated way. To date OPIN has facilitated 4 workshops in 2016 and 2017, held in Dublin, Edinburgh, Belfast and Aberdeen, which have exposed attendees to the benefits of Open Innovation, highlighted opportunities for learning and technology transfer from other sectors such as offshore oil and gas, and encouraged valuable industry collaboration.

The Ocean Energy Ireland Porta (www.oceanenergyireland.com)

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 which provide access to marine data, maps, tools, funding and information relevant to renewable energy site assessment, development and management.

The website and its content are continuously updated, and 2017 saw numerous new or upgraded features. The Marine Renewable Energy Atlas, an interactive GIS map of Ireland and its waters, was updated to include the most relevant, high quality downloadable data available. 2017 also saw the redesign of the media section of the website with a greater focus placed on user friendliness.

ITALY

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

Italy prioritized and incentivized the deployment of renewable energies by adopting a set of rules and regulations, which transposed the EU 2009/28/CE Directive into the Italian national legislation. As anticipated, the principles and the objectives of such regulatory framework are summarized in the National Action Plan for Renewable Energies of 2010, followed in 2013 by the National Energy Strategy, which has recently been updated - NES 2017. The former also reports the relevant Italian legislation already in force at the time, and classifies legislative acts as to their compliance to specific indications of the transposed Directive.

MARKET INCENTIVES

The latest indications and regulatory measures for the operative implementation of the National Strategy and Plan were issued in D.M. 23/06/2016. The Decree updated the support scheme previously regulated by DM 6 July 2012. The latter reviewed the preceding framework based on Feed-in Tariffs and Green Certificates, for renewable plants (other than Photovoltaic) in operation starting from 1 January 2013.

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

In general, the Decree grants a fixed tariff plus, in some cases, a specific premium, to provide incentives to net electricity fed into the grid. The fixed tariff is different according to each source, technology, and capacity range considered. Power plants with a capacity > 500 kW can only receive the incentive (fixed tariff minus electricity hourly zonal price, plus premiums if foreseen). Power plants with a capacity ≤ 500 kW can alternatively receive a Feed-in Tariff composed by the fixed tariff plus, in some cases, a specific premium. In the Dutch Auctions the maximum requested value of the tariff cannot be higher than a 2% discount of the reference value and the minimum value cannot be lower than a 40% discount of the reference value. The incentives last for the average conventional plant life of each typology of power plant. All the support schemes are managed by the Italian Energy Service Operator (Gestore Servizi Energetici - GSE), the body in charge of managing all the incentives to renewable energy.

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

TYPOLOGY OF POWER PLANT	CAPACITY	
	≥ 1 kW and ≤ 60 kW	> 60 kW and ≤ 5 MW
Wave and tidal power plants	Direct Access	Registry

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

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

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

The Directive 2014/89/EU on Marine Spatial Planning is also relevant for the specific Blue Energy Sector, 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 recently been transposed into the Italian legislation.

PUBLIC FUNDING PROGRAMMES

Italy relies on a public research programme aimed at maintaining and improving the national energy system, including the 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 orienting R&D activities towards the innovation of the electrical system, through funding under the EU principles that regulate State aid for Research and Development and Innovation. (Communication from the Commission 2014/C 198/01). The CERSE is composed of five members, appointed by the Minister of Economic Development, and is responsible for regulating public funding for research projects of general interest in the electricity sector.

The Ministry of Education, University and Research (Ministero dell'Istruzione, dell'Università e della Ricerca – MIUR) has launched two calls for proposals to grant funding for strategic research activities, including the Blue Energy sector. In 2017, the following Directorial Decree was issued:

- 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.

RESEARCH & DEVELOPMENT

RESEARCH COORDINATION

In the framework of the agreement between ENEA and the Ministry of Economic Development (MISE), under the Ricerca di Sistema - Ocean Energy Programme, ENEA has been long carrying out an intense coordination activity aimed at bringing together the major Italian actors in the ocean energy sector. The interrelation and standardization of the scientific and technological expertise of the Italian actors of the Ocean Energy sector were recognized as priority issues, and an unprecedented synergic effort has been set up for the technological innovation of marine energy plants, on which the recent National Research Action Plan 2015-2020 was able to draw for the constitution of the Blue Growth Technology Cluster.

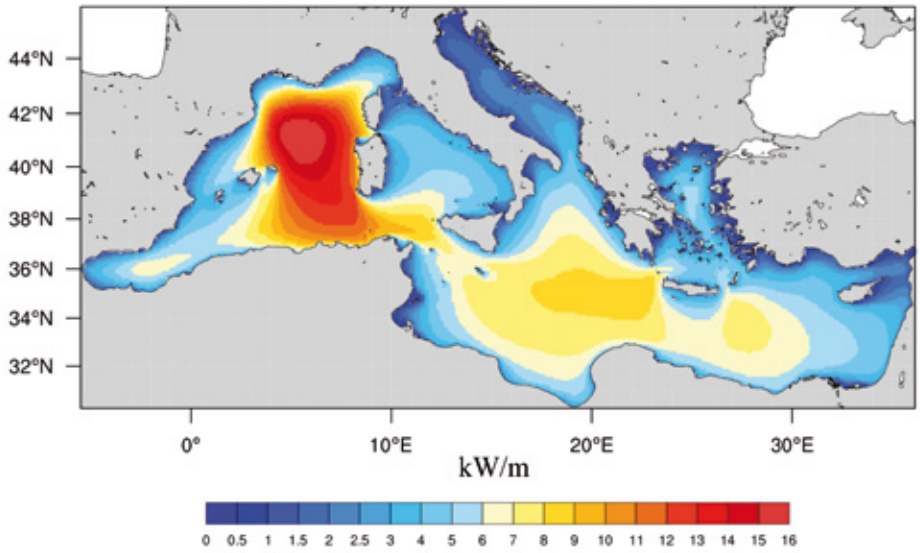
In May 2017, ENEA hosted the meeting "Italian contribution to the SET Plan on Ocean Energy", in accordance with the guidelines of the European Strategic Energy Technology Plan (SET-Plan). The meeting aimed at bringing together the Italian R&D activities in the Blue Energy sector, in order to design a common strategy for the acceleration of their development and for the deployment of innovative technologies in the transition to a low-carbon energy system.

SUPPORT TECHNOLOGIES

The positive international outlook for ocean energy deployment has induced researchers involved in subsidiary fields and potentially connected industrial players to approach this promising sector. They actively contribute to designing the building blocks of innovative ocean energy converters, either by developing ad hoc technologies or by optimizing existing ones, as well as to enlarge the existing database of environmental and product design constraints.

ENVIRONMENTAL MODELLING

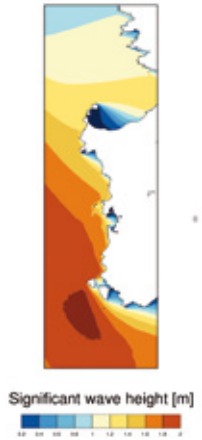
Prior to planning a renewable energy project it is essential to determine where sufficient resources exist, that guarantee adequate return on investment levels. For this reason, it is essential that reliable and updated maps, data and forecast systems are coupled to the engineering of devices, allowing optimal facility siting and a better understanding of site characteristics. As the size and complexity of the installations under study increase, the tools adopted to project or measure the resource become more and more critical and need to integrate a variety of modelling and monitoring techniques.



Mean Energy flux over the Mediterranean for years 2001-2010

ENEA performs ocean wave modelling activities aiming to both quantify ocean energy availability in the Mediterranean Sea and provide the information necessary to optimize the operational set-up of wave energy converters. A wave forecast system was developed by ENEA in collaboration with Enel Green Power, and validated, and has been operatively running since June 2013 (https://giotto.casaccia.enea.it/waves/).

Forecasts cover the entire Mediterranean basin, while nested higher resolution projections are provided for ten sub-basins along the Italian coasts. A sample projection for the western coast of Sardinia is shown on the figure on the right. When coupled to real-time measurements, the forecasting system can further support the operation of wave energy generation devices, predict actual electric power generation and give the alert in case of severe sea conditions.



DEVICE OPTIMIZATION

There are a number of Italian research institutions and enterprises involved in the development of devices for ocean energy conversion, design ad hoc numerical model for their most promising concepts:

- The **Politecnico di Torino** routinely performs numerical experiments in order to explore a large number of possible configurations for the devices that are being developed, from the first stages of the design process. Both in-house and commercial software tools allow the simulation of array pattern arrangements of devices, assessing the per-

formance and productivity of wave farms as a function of location, mutual hydrodynamic interaction and electric connection. Numerical tests also enable to estimate maintenance requirements and optimal operating conditions.

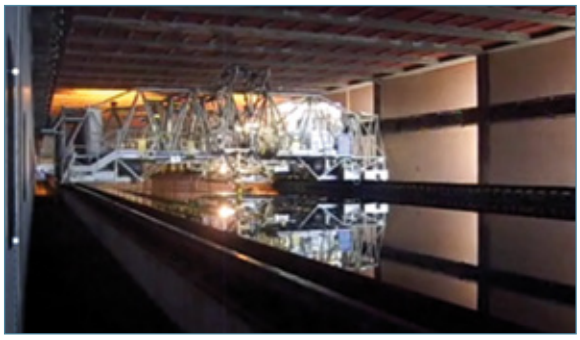
- The **University of Bologna** and **Politecnico di Milano** conduct numerical experiments to optimize the scaling and performance of wave power devices to be deployed off the Italian coast and in the Mediterranean environment. Their tests have demonstrated that several Italian locations and a large part of the Mediterranean coastline could be successfully exploited for marine energy production if properly downscaled devices are employed. They also develop non-linear models of the combined hydro-mechanic and electromagnetic behaviour of WECs, as well as of the hydrodynamic interactions of point absorber arrays (wave farms) in real wave fields.
- The **Università Sapienza** in Rome has recently developed an integrated open source tool, aiming at modelling the behaviour of floating wave energy converters under the ENEA-RSE-MISE agreement.
- **CNR-INSEAN** carries out research activities for the development and validation of advanced Computational Fluid Dynamics (CFD) models to simulate the operation of wave and tidal energy devices. Results are validated against experimental.

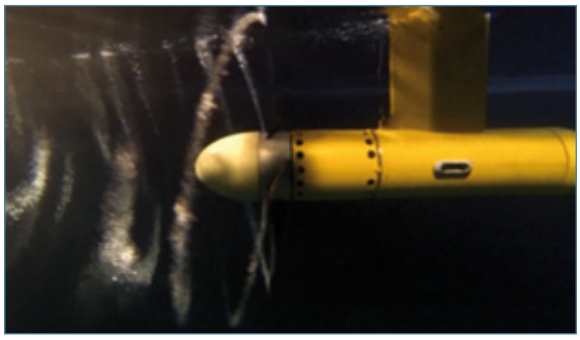
EXPERIMENTAL INFRASTRUCTURES

CNR-INSEAN offers research infrastructures that include world-class towing tanks and flume tanks, thus providing a relevant testing environment for wave, tidal, and offshore wind energy systems. The facilities provided are among the largest worldwide and consist of: a 460x13.5x6.5 m calm water tank, a 240x9x3.5 m wave tank and a 12x3.6x2.3 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 (a Horizon 2020 Project covering years 2017-2019), designed to accelerate the research development and deployment of offshore renewable energy. CNR has been invited to represent Italy in the Consortium and to promote a network of national stakeholders with expertise, capabilities and interests in marine renewables technologies.





CNR-INSEAN tank

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

The Natural Ocean Engineering Laboratory (NOEL) of UNIRC provides a unique testing infrastructure in the marine environment, where field tests can take advantage of the dedicated sensors and data acquisition centre, and be carried out with the support and assistance of specialized personnel (www.noel.unirc.it).

The NOEL at Reggio Calabria

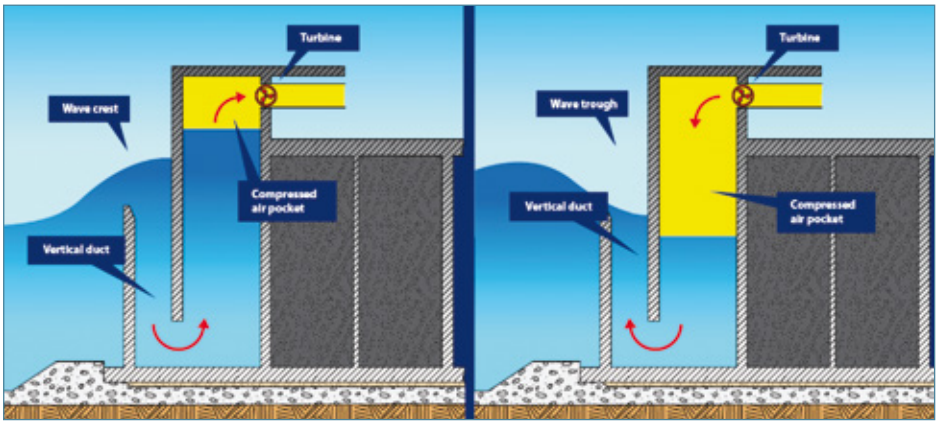
OPERATIONAL PROJECTS

In Italy there is an increasing interest in the exploitation of wave and tidal energy converters. In particular, wave energy converters (WECs) 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.

WAVE CONVERTERS

REWEC3

The Università Mediterranea di Reggio Calabria has been developing the REsonant Wave Energy Converter (REWEC3 – at present TRL 7), which is a particular 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. This device is composed of a chamber containing a water column in its lower part and an air pocket in its upper part. The air pocket is connected to the atmosphere via a small duct hosting a self-rectifying turbine. In addition, a REWEC3 also includes a small vertical U-shaped duct for connecting the water column to the open sea. The first full scale prototype is under construction in the port of Civitavecchia (Rome, Italy), as the Port Authority of Civitavecchia has recently 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.



Scheme of a REWEC3

OBREC (Overtopping Breakwater for Energy Conversion)

The Università degli studi della Campania "Luigi Vanvitelli" has developed a device denominated OBREC (Overtopping Breakwater for Energy Conversion), embedded into a breakwater and based on the wave overtopping process. The device consists of a rubble mound breakwater with a frontal reservoir designed to capture the wave overtopping a sloping ramp in order to convert wave energy into potential energy. Water stored in the reservoir produces energy by flowing through low head hydraulic turbines. A small scale (1:30) prototype of the OBREC was tested at Aalborg University (Denmark) during two experimental test campaigns in 2012 and 2014. A full scale, 6 m long prototype was installed in the port of Naples in 2015, along the San Vincenzo rubble mound breakwater, where sea depth is about 25 m and available wave power is estimated to be around 2.5 kW/m. The overall performance of the device is being monitored.

Breakwater equipped with the OBREC prototype in the port of Naples

SWEC (Inertial Sea Wave Energy Converter)

The Politecnico di Torino developed ISWEC (Inertial Sea Wave Energy Converter, TRL 7), 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. Research activities have started 10 years ago and led to the development of the technology industrialized by *Wave for Energy*, a spin-off of the Politecnico di Torino. In August 2016, the first full scale ISWEC prototype, with a nominal power of 100 kW, was moored 800 m from the coast of Pantelleria.

PEWEC (Pendulum Wave Energy Converter)

The Politecnico di Torino, in collaboration with ENEA, has also developed the point-absorber denominated PEWEC (Pendulum Wave Energy Converter, TRL 5). PEWEC is a passive system based on a pendulum positioned inside a hull, whose oscillation is converted into electrical energy via a Power Take-Off (PTO). A 1:12 prototype has been tested in the towing tank managed at CNR-INSEAN in Rome. Among the converters developed by 40SouthEnergy, the H24-50 kW was the first machine to reach commercial stage. The H24-50 kW is a small device, with a guiding member which sits on the sea floor or on a small support structure (depending on water depth and on tidal range), and a moving member above it, which moves under the action of waves or tides. H24 was first deployed off the coast of Marina di Pisa, Italy, and is operated and managed by Enel Green Power.

The PEWEC prototype at INSEAN

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. This device has been conceived for its integration in coastal structures (e.g. harbours and ports). It consists of a vertical pipe in which water moves upward and downward, following the wave motion. Inside the pipe, a hydraulic bi-directional turbine is positioned. 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 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

GEL system

Seapower s.c.r.l. (a consortium between private companies and the Department of Engineering of the University of Naples “Federico II”), in collaboration with Umbra Group, developed the GEL system (TRL 5), a wave energy converter designed to be installed near the coast or in shallow waters. The device consists of a floating body linked to a fixed frame that is left free to oscillate around a horizontal axis under the action of waves. The permanent magnet electric generator, integrated in the Power Take-Off (PTO) actuator/generator, allows the transformation of linear motion induced by waves into rotary motion of the generator rotor. A 1:5 scale and a full scale prototype have been tested in the wave tank located at the Department of Industrial Engineering (DII) of the University of Naples “Federico II”. It has reached TRL 5 and it is ready for testing in real sea conditions.

TIDAL TURBINES

KOBOLD turbine

The Aircaft Design & Aero flight Dynamics Group (ADAG) of the Università di Napoli "Federico II", in cooperation with SEAPOWER Scrl, has long been designing systems for the extraction of energy from marine currents. They have developed and patented the KOBOLD turbine (TRL 7), a rotor mounted on a vertical shaft, which produces mechanical energy by exploiting marine currents. A platform equipped with a Kobold turbine of the diameter of 6 m with three blades with a span of 5 m, built by the Ponte di Archimede Company, was installed in the Strait of Messina in the year 2000 and is still in operation. The nominal power output is 30 kW and the device is connected to the distribution grid.

The Kobold installation

GEM device

ADAG and Seapower, in cooperation with Ing. Morrone, have also designed GEM, the Ocean's Kite (TRL 7), 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. After the experimental phase in towing tank, a first full scale prototype has been deployed in Venice lagoon. The nominal power of the device is 100 kW with 5 knots of current speed; in the Venetian lagoon, where the maximum flow current speed is around 3 knots the power that can be produced is about 20 kW. A full scale prototype of 300 kW will be installed in the Strait of Messina.

The GEM device

RELEVANT NATIONAL EVENTS

Recently, the EU Interreg-MED Programme has launched the horizontal project InnoBlueGrowth - "Horizontal Communication & Capitalization project for Innovation in Blue Growth at Mediterranean level" - with the aim to implement concrete actions (i.e. a communication strategy, community building initiatives and capitalization events), to build cohesive stakeholders communities sharing common interests and issues and to enlarge the spectrum of potentially connected industries. The project is coordinated by the National Interuniversity Consortium for Marine Sciences (CoNISMa, Italy). The "Launch of Blue Growth Community in Med Area" took place in Rome, 6-7 April 2017.

Italy is actively participating in the modular InnoBlueGrowth projects PELAGOS and MAESTRALE:

- **PELAGOS project** (https://pelagos.interreg-med.eu/) is specifically dedicated to ocean energy and offshore wind energy and aims to define a management and coordination system connecting the different components of the Quadruple Helix, schematizing the linkages and the potential conflicts between knowledge production and knowledge use in the field of Blue Energy. It will connect the different stages of the production process, from the R&D activities to their operative implementation, to the creation of new interfaces with potential customers and the public opinion. To this end, a permanent Cluster of national hubs is being established. The Italian hub Demonstration Event took place at ENEA premises in Rome on 29 September 2017, and was followed by a B2B Event in Monfalcone (GO), 29 November 2017, and by a Capacity Building Event on entrepreneurship and technology transfer in Rosolina (RO), 13 December 2017
- **MAESTRALE project** (https://maestrale.interreg-med.eu/) has started to lay the foundations for a strategy for the deployment of maritime energy in the Mediterranean area. Based on a survey of existing and innovative technologies, barriers and potentials in participating countries, MAESTRALE aims to broaden the sharing of knowledge among scientists, policy makers, entrepreneurs and citizens and encourage effective measures and investments for Blue Growth. MAESTRALE's first Transnational Meeting took place in Rome, 4 -6 April 2017.

The Horizontal Project InnoBlueGrowth, in its turn, organized the transnational event "Innovation for the development of marine energies in the Mediterranean", Naples, 27-28 November 2017, where the first results of MAESTRALE and PELAGOS were presented.

JAPAN

SUPPORTING POLICIES FOR OCEAN ENERGY

In 2013, the Government of Japan reformulated and published **The Second Basic Plan on Ocean Policy** which states the importance to "realize a new oceanic state in harmony with the peaceful and positive development and use of the oceans with the conservation of the marine environment, under international cooperation based on the United Nations Convention on the Law of the Sea and other international agreements." This plan addresses the promotion and creation of marine industries and encourages the public and private sector to improve frameworks for the development of marine renewable energy in the country. It also remarks the need for the establishment of comprehensive strategies including policy support measures, under a coordinated approach between the industrial, academic and governmental sectors.

RESEARCH & DEVELOPMENT

Ocean energy projects in Japan are supported by the New Energy and Industrial Technology Development (NEDO), by the Ministry of Environment (MOE) and by the Ministry of Education, Culture, Sports, Science and Technology (MEXT). NEDO has been encouraging R&D for wave energy, tidal energy, ocean current and ocean thermal energy conversion. Under a contract with NEDO, the IHI Corporation has been developing a floating ocean current technology, to use in ocean currents, such as the Kuroshio Current, along the coast of Japan.

TECHNOLOGY DEMONSTRATION

A new test site has been approved for ocean current projects, at Kagoshima Prefecture. In this site, IHI Corporation tested their 1:3.5 scale floating ocean current demonstration project called "Kairyu" (a twin rotor 100 kW turbine), during 2017. There are plans for continuation and a 2 MW floating device has been designed to be deployed at 200 – 1000 meters water depth (50 meters below the water surface).

Source: IHI Corporation and NEDO

Mitsui Engineering and Shipbuilding entered into a lease agreement with Ocean Power Technologies for the installation and demonstration of a PB3 PowerBuoy. The wave energy convertor was deployed off Kozu island for extended testing during 2017.

PB3 PowerBuoy deployment
Source: Ocean Power Technologies, Inc.

Wave Energy Technology conducted demonstration trials on its scaled floating wave energy prototype off Kobe city in Japan. The 1.4 meters in diameter device demonstration was conducted and is leading towards the development of a up to 1.2MW commercial-scale unit

Wave Energy Technology deployment
Source: Wave Power Technology

Future projects include the MOE sponsored tidal turbine installation off the Goto Islands, Nagasaki Prefecture. A single Open Centre turbine supplied by Naval Energies is planned for deployment in 2019-2020 working in partnership with local partners Kyuden Mirai Energy Co., Inc, Nippon Steel & Sumikin Engineering Co., Ltd., and NPO Nagasaki Marine Industry Cluster Promotion Association.

KOREA

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The national strategy for the development of ocean energy systems in Korea, approved by the National Science and Technology Council in 2015, was established based on the "Mid-term and Long-term Clean Ocean Energy Development plan 2015-2025", which was written by both MOF (Ministry of Oceans and Fisheries) and MOTIE (Ministry of Trade, Industry and Energy). It emphasized the key action plan to stimulate R&D and to commercialize technologies related to the ocean energy systems.

Last year, the Korean Government announced the new "Action Plan for Renewable Energy Policy 3020" for reducing the footprint of fossil fuel by sharing up to 20% of a total national electricity demand from renewable energies, such as wind and solar, by 2030. The MOF has also clarified the goal by confirming a new plan for developing and disseminating the ocean energy systems in "2030 Ocean Energy Development Plan" to meet the Government's new energy policy. This new plan includes a construction of 1.5 GW ocean energy infrastructures and promotion of new industries in the ocean energy systems by cultivating specialized companies and establishing supply chains. In order to construct a 1.5 GW ocean energy infrastructure additionally by 2030, it plans to build new infrastructures including wave energy systems of 220 MW, hybrid power generation systems of 300 MW, and tidal energy systems of 700 MW on the existing Sihwa Lake tidal power plant of 254 MW.

MARKET INCENTIVES

The renewable portfolio standard (RPS) was established in 2012 to enforce utility companies with the capacity of over 500 MW to provide an obligatory portion of the total electricity production with renewable energy, which was 4.0% in 2016. The market incentive plan, known as tradable Renewable Energy Certificate (REC), supplements the RPS policy.

The values of REC are currently given as 2.0 for tidal current, 1.0 for tidal barrage with embankment and 2.0 for tidal barrage without embankment, whereas the value of REC for the wave and thermal ocean energy is yet to be determined. MOF is currently conducting research to adjust the value of REC for the tidal energy systems and to decide the new REC values for WEC and OTEC in order to promote the active participation in the ocean energy development from major companies.

PUBLIC FUNDING PROGRAMMES

MOF and MOTIE provide public funding for ocean energy R&D, as well as demonstration projects. They invested a total of USD 200 million for ocean energy technology development projects from 2000 to 2017. MOF funding focuses mainly on open sea demonstrations under the "Practical Ocean Energy Technology Development Programme", while the MOTIE primarily supports the fundamental R&D projects under the "New and Renewable Technology Development Programme".

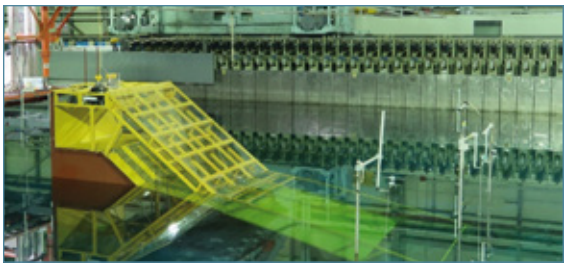
RESEARCH & DEVELOPMENT

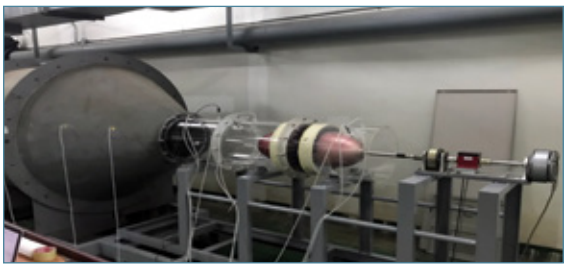
Wave Energy Converter with Energy Storage System Applicable to Breakwaters on Remote Island

The present research project is aimed to establish the commercializing foundation for the ocean energy by developing wave energy converters and the integrated energy storage system (ESS), applicable to the breakwaters in harbours and ports on remote islands. Conceptual and basic designs of the wave power generation system were carried out from 2016 to 2017. Since most of the breakwaters are sloped, an oscillating water column (OWC) with sloped shape was designed. Numerical and model tests showed that the sloped OWC has acceptable performance compared to

the existing vertically installed OWCs. A high efficient turbine was developed by applying a ring to an impulse turbine. A permanent magnet synchronous generator (PMSG) and connected power conditioning system (PCS) were developed taking into consideration of the maintenance and the mitigation of vibration and noise of the system. The ESS and micro gird system was implemented by analysing the electrical environment of the installation site, Chu-ja Island of Korea.

WEC applicable to breakwaters on remote island

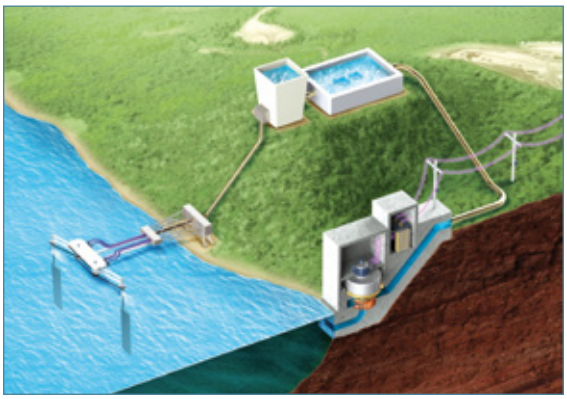




Model tests for the OWC & impulse turbine

Tidal Current and Pumped Storage Hybrid Power Generation

The present research project is aimed to develop a tidal current and pumped storage hybrid power generation system, which is combined with the dual flapping type system as tidal current generator. The flapping type tidal current generator in the changed power transmission of vertical arrangement can be applied to pump seawater through its mechanical power, which becomes a new concept in hybrid power generations. The development period for this project is approximately three years and is supported by the New & Renewable Energy R&D programme of the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by MOTIE. The main research contents for this project are (1) the development of design technology for the tidal current and pumped storage hybrid power generation system and (2) the demonstration of indoor and outdoor experiments for the tidal current pumped storage hybrid power generation system.



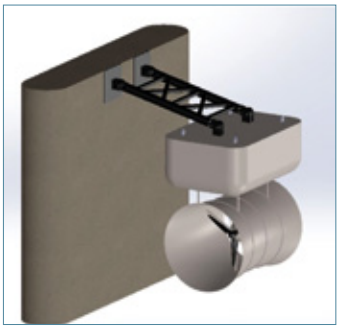
A schematic of the tidal current and pumped storage hybrid power generation system

Design and Performance Test of Tidal Turbine for Self-Sufficient Energy Bridge

Around long span offshore bridges between islands or island and mainland, there are abundant ocean energy resources such as tidal current and wind induced waves. Especially strong current is induced near the bridge area owing to the narrow channel where water flow can concentrate. The goal of this project is to develop an optimal tidal energy converter for supplying electricity from tidal energy into the bridge and to commercialize the zero emission bridge technology to reduce operational costs for energy consumption and environmental effects. The tidal current power system is being designed to be suitable for the bridge, and it includes tidal energy converter (turbine, duct, generator, etc.), buoyancy tank, ESS for load levelling, and comprehensive control and monitoring system. This project is being carried out for 3 years from 2015 to 2018 with the financial support of KETEP by Korea Marine Equipment Research

Institute (KOMERI). In 2017, the design and manufacture of the ducted tidal energy converter, floating body, power converter and monitoring system were completed. The open sea test is scheduled for March 2018. This technology is expected to accelerate the commercialization of tidal energy converters that facilitate the construction at low cost compared to the existing systems and the application not only for the bridge but also the discharge channels of power plants, rivers and island areas for isolated grid.

Long span bridge on narrow channel

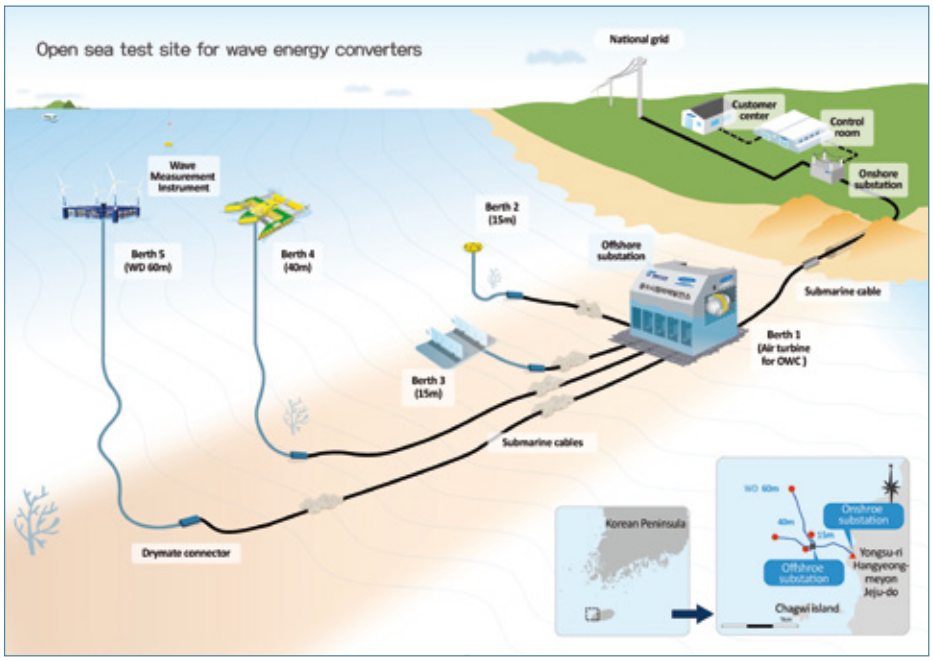


Conceptual design

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

MOF has been supporting construction projects of the open sea test sites for wave energy converters and tidal energy converters. The construction project of test center for the wave energy converter started in May 2016. The western shore of Jeju Island was selected as the test site, where the Yongsoo OWC wave energy plant is installed nearby. The Yongsoo OWC will be utilized as the offshore substation for the open sea test site. The project is expected to be finished by December 2019. Korea Research Institute of Ships & Ocean engineering (KRISO) has been in charge of developing the project. A number of cables from five different berths will be connected to the offshore substation and the grid system with the allowance capacity of 5 MW. KRISO surveyed and designed the cable routes from the offshore substation to each berth in 2016. The consenting process for ocean space occupation and electrical connection started in 2017. The cables and offshore substation will be constructed in 2018. The Floating Pendulum Wave Energy Converter (FPWEC), with the capacity of 300 KW, is expected to be tested in the fourth berth, with the water depth of 40 m, in 2018.



Open sea test site for wave energy converters

The construction project for open sea test bed with 5 berths of 4.5 MW grid connected capacity for the tidal energy converters is being carried out from May 2017 to December 2021 by KIOST. Furthermore, the performance test facility for components of tidal energy converters, such as blade and drive train, will also be constructed in this project. The southwestern waters of Korean peninsula are primarily considered as the tidal energy test site, where the Uldolmok tidal current pilot plant is installed nearby.

OPERATIONAL PROJECTS

500 kW Yongsoo OWC Pilot Plant

The construction of the Yongsoo OWC pilot plant was completed in July 2016 and installed at 1.5 km away from the coastline of Jeju Island. The plant, equipped with impulse turbines and 250 kW generators, and grid-connected by the 22.9 KV AC underwater cable, is currently under the trial run. By analysing the early performance data from the trial run, the maximum efficiency for the OWC chamber, the turbine and the generator turned out to be equal to 52.7%, 40.0% and 91.7%, respectively.

SUPRC 20 kW OTEC and 200 kW HOTEC Plants

Currently, the 20 kW OTEC and 200 kW HOTEC plants are in operation and conducting the performance test at the Sea Water Utilization Plant Research Centre at Goseong-gun, Gangwon-do, a subsidiary research base of KRISO dedicated to seawater and thermal energy application. The 20 kW OTEC plant uses 5°C of deep-sea water as a heat sink and 26°C of surface seawater as a heat source, and it exhibits the efficiency of 2.1%. While the 200 kW HOTEC plant also uses 5°C of deep sea water as heat sink, it utilizes readily available thermal energy resources like geothermal energy near the coast, waste heat from ships, woodchip gasification, and other types of nearby power plants to increase the heat source temperature up to 75°C which exhibits the efficiency of 7.7%. Currently, KRISO is preparing to conduct a demonstration experiment to verify the validity of the thermal energy from a 500 kW woodchip gasification plant for 200 kW HOTEC plant

PLANNED DEPLOYMENTS

Active-Controlled Tidal Current Power Generation System

The project is aimed to develop and demonstrate the active-controlled, high efficiency and low cost 200 kW Tidal Energy Converter (TEC), with the operating capacity applicable to the shallow sea conditions (about 20 m). The TEC was manufactured by KIOST and its caisson-type substructure was designed, fabricated, and deployed by Hyundai Engineering and Construction 2016. In 2017, the performance of PMSG and main drive train was evaluated using a portable dynamo test facility, and the internal communication system and the active rudder device for automatic and passive yaw control have been also tested in indoor and underwater environments. The TEC will be installed at the Uldolmok test site for open sea test in early 2018.

Dynamo test for PMSG and drive train of 200 kW TEC

Floating Pendulum Wave Energy Converter

Since 2012, the development project for the 300 KW wave energy converter has been carried out by KRISO with the support from MOF. In 2016, the construction of Floating Pendulum Wave Energy Converter (FPWEC), featured with a pendulum activated, high efficiency and high persistence rotary-vane hydraulic pump was completed and deployed to its operation site, waiting to be prepared for the sea test site. In 2017, the remote operating and monitoring system was tested and optimized. The FPWEC is planned to be tested using the forth berth of the open sea WEC test site on Jeju Island in mid-2018.

300 kW Floating pendulum wave energy converter in port

1 MW KRISO-OTEC

For the commercialization phase of the OTEC development, KRISO is in charge of manufacturing 1 MW OTEC demonstration plant. The plan is to complete the installation on a barge and perform the short-term operation in the eastern coast of South Korea by 2019, followed by transferring and construction as on-land type to conduct long-term operation at South Tarawa, Kiribati, in 2020. Until 2017, KRISO manufactured the 1.2 MW turbine generator and condensers, etc., and investigated the external environmental force of the plant site in South Tarawa for intake pipe installation. Furthermore, the Environment Impact Assessment (EIA) was conducted for 1 MW OTEC plant. Based on the result of 1 MW OTEC plant operation in Tarawa, KRISO is planning to design and receive the Development Approval (DA) for the 1 MW OTEC plant and the AIP for the 10 MW OTEC plant for multi-purpose industrialization.

Offshore 1 MW OTEC

On-land 1MW OTEC

MEXICO

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

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

To strengthen the operation of the Mexican Energy Innovation Centres (CEMIEs), the Ministry of Energy, through the Energy Sustainability Fund, developed Technological Roadmaps (TRM) for different renewable energies, including geothermal, ocean energy, solar photovoltaic, solar thermal, wind and bioenergy. These TRM help in the definition of the pathway and initiatives for the strategic planning aimed to increase the clean energy generation in the country. The TRM are focused on strengthening technological capabilities, including infrastructure, specialized human resources and technological services. They also prioritize the actions to reach the 2030 goals for installed capacity, as well as detailed activities, identification of stakeholders, targets and milestones in a specific timeframe. Based on these assumptions, it is estimated that ocean energy can contribute with 500 to 1000 MW of installed electrical capacity by 2030.

MARKET INCENTIVES

Mexico offers Clean Energy Certificates to consumers which use clean electricity or reduce emissions by processes defined in Article 3, section XXII of the Electricity Industry Law. By 2018, for the power generation sector must buy at least 5% of these clean energy certificates. This figure is expected to increase to 5.8% by 2019, 7.4% by 2020, 10.9% by 2021 and 13.9% by 2022. Currently, SEMARNAT (Ministry of Environment and Natural Resources) is working on the preparation of a carbon market which aims to create national and international mechanisms to benefit low carbon initiatives, however it will take time to see how this market can integrate and interact with clean energy technologies.

PUBLIC FUNDING PROGRAMMES

The Energy Transition and the Sustainable Use of Energy Fund was created by the Ministry of Energy and the National Science and Technology Council 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 based on:

- The encouragement of the use and application of clean technologies in all productive chains;
- The diversification of primary sources of energy;
- The establishment of a standardization programme for energy efficiency;
- The promotion of measures for energy efficiency, as well as saving energy;
- Ensuring that the population has access to reliable, timely and easily accessible information regarding the energy consumption of any electrical equipment;

The Sustainable Energy Fund is intended to facilitate any initiative to develop areas of energy efficiency, renewable sources, use of clean technologies and the diversification of primary sources of energy through four lines of action:

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

RESEARCH & DEVELOPMENT

Through CEMIE-Oceano:

1. The Salinity Gradients Group has been working in two main directions: a) investigating natural salinity gradient resources in the Mexican Pacific and Atlantic; and b) experimenting with the acquisition of energy from salinity gradients. Both research areas are new in Mexico and efforts have been directed towards investigating these fields elsewhere. The team has begun a) to characterize salinity gradients around Mexico: three coastal sites will be monitored in order to quantify temporal variations of the gradients and their energy potentials, and b) to test existing membranes, materials and prototype configurations. Using the method of Reverse Electro Dialysis (RED), the best cost-energy ratio (production-life) of these components is being determined.

2. The Tidal and Current Group has been gathering existing information on bathymetry and currents for two test sites. For the Cozumel region, coastal bathymetric data is already available, and field campaigns are being organized to gather multibeam information for the Cozumel Channel. Acoustic current profiler data for a deep mooring (400 m) and a shallow mooring (15 m) from existing projects is also available. The assessments of these data show that the coastal current is too weak and too variable to be a viable energy source. The proximity of fragile ecosystems (coral reefs) also precludes the use of this energy source here. The deep water currents are a much better option, with unidirectional currents of more than 1 m/s 62% of the time. However, connection to the energy network is difficult at such depths. Field measurements of currents and ambient turbulence at 50 m and 75 m depths are planned, much closer to shore but deep enough to find stronger currents. For the Gulf of California field campaigns will be carried out. Instrumentation has been tested and the teams are ready to start the deployments. There are also advancements in materials for biofouling and on the development of new prototypes. Numerical modelling of ocean currents at national scale is being performed to assess this resource in areas previously overlooked.

3. The Ecology Group has been working on the regional effects on the distribution and abundance of marine mammals following installation of alternative marine energy plants, lifecycle databases, the determination of regional effects of the installation of oceanic energy plants on key species and coastal ecosystems, detailed geological-geomorphological assessment of potentially suitable sites for the location of coastal power plants in Veracruz, the selection of potential installation sites to minimize the effects on the distribution and biodiversity of coastal species and the evaluation of the relationship of the sea with the bioclimate and with energy consumption in Mexico.

4. The Wave Energy Group is verifying the operation of two WECs for possible installation in the Mexican Pacific. The design and operational conditions of these WECs have already been characterized for the whole country and possible ways for the integration of these devices to the electrical network are being investigated.

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

CEMIE-Oceano continues to conduct studies and acquire oceanographic measuring equipment to establish two natural sites for testing wave energy devices in Ensenada, Baja California, and ocean current energy devices in the Cozumel Canal, Quintana Roo under natural conditions.

PLANNED DEPLOYMENTS

Projects being developed, to be installed in the sea by CEMIE-Oceano:

- Wave energy device – Sauzal Port, Baja California;
- OTEC – Acapulco, Guerrero;
- Wave energy device, Lazaro Cardenas, Michoacan.

RELEVANT NATIONAL EVENTS

Workshops organized by CEMIE-Oceano:

Workshop on the environmental impact of electric energy generating devices in the sea
Mexico City (CEMIE-Oceano), 25-26 May 2017

Course-Workshop on Ocean Thermal Gradient Energy
Mexico City (CEMIE-Oceano), 30 August to 1 September 2017

DEMEX – Mexico International Renewable Energy Conference, MEXIREC 2017
Mexico City (Ministry of Energy), 11-13 September 2017

Course-workshop on salt energy gradients
Yucatán, Mexico (CEMIE-Oceano), 2-3 November 2017

Bilateral meeting University of Edinburgh - CEMIE-Oceano
Mexico City (CEMIE-Oceano), 21 November 2017

Conferences organized by CEMIE-Oceano:
Marine current energy (30 March 2017)
Stephanie E. Ordoñez Sánchez, University of Strathclyde, UK

Use of salt gradient energy in river mouths (22 May 2017)
Oscar Álvarez Silva, Universidad del Norte, Colombia

Challenges for marine renewable energy implementation (24 May 2017)
Teresa Simas, WavEC, Portugal

Challenges for ocean thermal energy conversion (OTEC) in Japan (30 August 2017)
Yasuyuki Ikegami, Saga University, Japan

Technical readiness of OTEC to achieve sustainable development goals (31 August 2017)
Hyeon-Ju Kim, Korea Research Institute of Ships & Ocean Engineering (KRISO)

Marine Renewable Energy (1 September 2017)
Luis A. Vega, University of Hawaii, USA

Workshop on OTEC, 1 September 2017

MONACO

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

On the instigation of H.S.H. Prince Albert II, the environment and subjects related to sustainable development are among the most important political priorities in the State of Monaco, on both a national and international level. The actions of the Princely Government take into account the topics of biodiversity, preservation & management of natural resources and the reduction of greenhouse gases and also a specific policy towards the establishment of a sustainable city.

The Principality of Monaco joined the OES in June 2013. This action was part of the Government targets for combating climate change and recognizing the relevance of international cooperation. Monaco is a coastal country with 2,02 km2 of area, bordered by the Mediterranean Sea, with a coast length of 3829 m.

The Government pursues a sustainable development policy aimed at achieving full compliance with the Principality's undertakings. This intention is expressed through local initiatives on the Monegasque territory and through cooperation work in developing countries.

In line with the provisions of the Kyoto Protocol, Monaco has set itself the target of improving energy efficiency by 20% and achieving 20% of final energy consumption from renewable sources by 2020. To this end, the deployment of the Climate and Energy Plan includes technical, regulatory, financial and awareness-raising campaigns.

During his participation at the 21st United Nations Conference on Climate Change in 2015 in Paris, H.S.H. Prince Albert II of Monaco reaffirmed commitments for the Principality. Monaco will take part in efforts to stabilise the global warming of the planet by reducing its greenhouse gas emissions by 30% in 2020, 50% in 2030 and to achieve carbon neutrality in 2050 with respect to the reference date of 1990. In addition, the Princely Government funds projects in several developing countries, forming part of the Clean Development Mechanisms (CDMs) laid down by the Kyoto Protocol.

PUBLIC FUNDING PROGRAMMES

Within the framework of the Climate and Energy Plan and the COP21 agreement, a dedicated funding instrument has been created and it is financed by

- The money generated through the sale of electricity and creates funds for the promotion of renewable energies and other sustainable development objectives.
- The National Green Fund within the Government budget.

Furthermore, the Government holds 100% of the shares in this venture capital firm, known as "Société d'Aide à la Création et au Développement d'Entreprise" (SACDE), the aim of which is to support innovative Monegasque companies.

Those with innovative projects (under development) can contact the Government, which studies opportunities for financial support - contributing to the share capital of the entity to be created in the Principality, additional loans, etc.

MARINE SPATIAL PLANNING POLICY

In Monaco there are:

- 2 Marine Protected Areas;
- 3 Restricted Areas;
- 7 Areas of ecological interests.

It is implemented by the technical departments as the Department of Maritime Affairs & the Department of the Environment, the Marine and Airport Police Division and one NGO: Association Monegasque pour la Protection de la Nature.

Permitting and Licencing Process for Ocean Energy projects: A proposal has to be sent to the Ministry of Public Works, the Environment and Urban Planning, then if the project is of interest for the Principality of Monaco, a technical committee will be set up to analyze and implement the project.

RESEARCH & DEVELOPMENT

The OPTIMA PAC initiative is a research project that checks how well the existing demonstration projects in Monaco perform against three targets:

- Offering an industrial range of sea water heat pumps compatible with sustainable development;
- Controlling environmental impacts;
- Optimising design and operation.

Then, various buoys have been installed in partnership with the National Centre for Archiving Swell.
Measurements and the department of public works. This operation is mainly linked to Monaco's six-hectare offshore extension project.

Live data on the website: http://candhis.cetmef.developpement-durable.gouv.fr/

TECHNOLOGY DEMONSTRATION

OPERATIONAL PROJECTS

In Monaco, the sea is used as a renewable energy source for the development of a heat pump system. The first heat pump with sea water in Monaco dates back to 1963.80 sea water heat pumps produce 20% of the energy consumed in the Principality (about 191 GWh/year).
Many buildings located on the coast benefit from this reversible system, for heating in winter and air-conditioning in summer. These save the equivalent to 15,000 metric tons of oil per year.

PLANNED DEPLOYMENTS

The number of sea water heat pumps is expected to increase in the near future due to some on-going projects.

RELEVANT NATIONAL ACTIVITIES

10 - 11 April 2017: 32nd OES ExCo Meeting in Monaco
11 - 13 April 2017: EVER Monaco (Ecologic Vehicles/Renewable Energies), with a roundtable dedicated to Marine Energies.

NETHERLANDS

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The potential of ocean energy has been studied since the 80s and recently the Ministry of Economic Affairs and the Ministry of Infrastructure have acknowledged the energy and export potential. Business and other organizations joined forces in a trade association called the EWA (Netherlands Energy from Water Agency).

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.

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

A spatial analysis of the potential of the North Sea with a view to 2050 has been made, with regard to offshore wind and ocean energy. The North Sea Spatial Agenda indicates a potential of up to 2000 MW of tidal current and wave energy to be possible, if techniques are developed further to fit the Dutch situation, with relatively low tidal heads and speeds. Although in some cases there is fast flowing water of estuaries, and near barriers there are places with high speeds up to 5 m/sec.

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

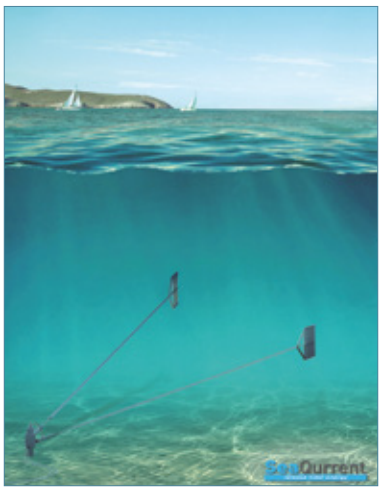
The Netherlands' Department of Waterways and Public Works (Rijkswaterstaat) supports initiatives to generate energy, but on the other hand is responsible for protecting the Netherlands from flooding from the North Sea. In general, the current projects were supported generously and erected quickly.

MARKET INCENTIVES

For 2018, the generic national subsidy scheme (SDE, stimulating renewable energy) has also been opened for tidal current, wave energy and free flow energy. The maximum subsidy for renewables has been reduced to €0,13/kWh, due to the decreased costs of offshore wind, which is considered as the benchmark.

PUBLIC FUNDING PROGRAMMES

In addition to the above mentioned feed-in tariff (OPEX subsidy), there are generic funding programmes (CAPEX subsidy) for all relevant types of renewable energy. The Ministry of Economic 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.



Offshore 1MW OTEC demonstration plant

RESEARCH & DEVELOPMENT

In 2017, **SeaQurrent** started the developed of a tidal kite. The concept has been validated by independent universities and research institutes. The founders of SeaQurrent have a background in the offshore oil and gas industry, a pilot and demo is planned for the coming years.

The positive results in 2017 in the pilot plant of **REDstack** on the Afsluitdijk allow for scaling-up to a 1MW demo pilot plant. Together with four partners, a "Blue Energy deal" was signed in 2017 for this purpose. 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. 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 easy scalable, 24/7 available and the only "waste" product is brackish water. Blue Energy is a perfect candidate for base-load energy production and application in the energy-mix.

In 2017, Tocardo further tested their 1.25 MW tidal power plant in the Eastern Scheldt. Tocardo is now planning a 2 MW successor, also consisting of 5 separate turbines.

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

Main activities in the test sites during 2017:

- Re-development of the Texel offshore open water test site in Marsdiep
- Permitting and financing for the future Grevelingen Tidal Technology Centre
- Development of the test site for Slow Mill off the coast of Texel
- Development for a pilot Blue Energy plant in Katwijk (RED-Stack)

OPERATIONAL PROJECTS

- List of operational projects during 2017:
- Tocardo Den Oever; tidal current, free flow
- BlueWater Delft; tidal energy, free flow
- REDstack Sneek; salinity gradient energy
- Bluerise Delft; OTEC
- Arteq Power Rotterdam; OTEC
- Tocardo VAWT; tidal current, Vertical Axis Wave Rotor Technology
- Tocardo 1,2 MW tidal plant in Eastern Scheldt Storm surge barrier
- Tocardo 300 kWp tidal array in Afsluitdijk in the Stevin Sluizen
- RED-Stack pilot for Reverse Electro-Dialysis on Afsluitdijk

Led by Tocardo, the project brings together Orkney based companies EMEC and Leask Marine, and French research institute IFREMER. Tocardo has already been working with international shipyard DAMEN, as well as Leask Marine, Bryan J Rendall Electrical and Aquatera in Orkney for the system deployment. The floating tidal device was successfully moored and connected via subsea cables to the substation at EMEC's Fall of Warness grid-connected tidal test site in Orkney in May 2017. Tocardo's EMEC installation is part of the InToTidal project, supported by European Commission's funding program Horizon 2020 with €2 million. The platform was first deployed off Texel island in the Netherlands in 2015. It was originally equipped with Tocardo's T1 turbine that had the capacity of 100 kW, which was later replaced by T2 turbine, doubling its capacity.

NEW ZEALAND

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The NZ Government has a long-running commitment to a goal of 90% renewable electricity supply by 2025, with an additional target of 100% renewable electricity supply by 2035 being introduced in late 2017 by the new coalition Government. Following this, there is a target for a net zero emission economy by 2050.

In addition to these over-arching targets, the NZ Energy Efficiency and Conservation Strategy for 2017-2022 identifies the three priority areas of:

- Renewable and efficient use of process heat
- Efficient and low-emissions transport
- Innovative and efficient use of electricity.

The first two of these priorities are likely to involve a shift in energy use towards electricity, thus effectively making the renewable electricity targets more stringent.

MARKET INCENTIVES

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

PUBLIC FUNDING PROGRAMS

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

RESEARCH & DEVELOPMENT

Brett Beamsley of MetOcean Solutions was awarded funding from the Sustainable Seas National Science Challenge to develop a software tool for the prediction of the physical oceanographic effects of large scale tidal current generation. This project is in collaboration with Ross Vennell of the University of Otago and the Cawthron Institute, who has led projects in this area for a number of years.
(http://sustainableseaschallenge.co.nz/news-updates/6-new-innovation-fund-projects)

TECHNOLOGY DEMONSTRATION

OPERATIONAL PROJECTS

The US-based company NWEI, in partnership with NZ-based Energy Hydraulics (EHL) and others, concluded testing of the Azura Wave device at the US Navy's Wave Energy Test Site at the Marine Corps Base Hawaii in late 2016/early 2017. During approximately 18 months of in-sea testing they were able to achieve 97% availability. This project is a continuation and evolution of the initial technology development known as WET-NZ.

PLANNED DEPLOYMENTS

Northwest Energy Innovations (NWEI) and their partners have developed a detailed design of a larger-scale Azura Wave device and are awaiting funding.

NORWAY

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

Norway currently has no dedicated policy towards ocean energy, but ocean energy is included in more general renewable energy policies and programmes.

MARKET INCENTIVES

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

The Norwegian energy production that may be certified for certificates until 31.12.2020 in the so called transitional scheme; however, Norwegian projects will receive certificates only until 31.12.2035, even if the project is approved for certificates under the transitional scheme.

PUBLIC FUNDING PROGRAMMES

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

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

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

RESEARCH & DEVELOPMENT

Stadt Towing Tank (STT) was founded in 2007 to deliver test and research services to the marine industry. The main market for STT has been ship designers in the maritime cluster of north-western Norway, but projects related to renewable energy have also been tested. Wave energy converters, windmill installation concepts, windmill foundation solutions and windmill service vessels are among the renewable energy projects.

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

Runde Environmental Centre (REC), located on Runde Island on the Norwegian west coast (http://www.rundecentre.no), can accommodate WEC plants for test and demonstration at several sites. One has a 3 km/0.5 MW sea cable to shore with grid connection. REC facilitates preparations, licensing, deployment and monitoring of the WECs, and works also on other forms of ocean energy, building national competence and capacity.

REC hosts other subsea 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 ocean energy devices in the area. The same applies to the wave forecasting model installed, in co-operation with the Norwegian meteorological office. REC is currently hosting Waves4Power's grid connected 100 kW prototype.

OPERATIONAL PROJECTS

The first operational, grid connected wave energy buoy project in Norway was launched on 2 June 2017. The Swedish technology company Waves4Power has developed and produced a 100 kW energy converter, which is currently undergoing long term grid connected testing at the Runde Environmental Centre (REC). The anchored buoy – Wave-EL – is connected to a stand-alone buoy-mounted transformer. The transformer is readied for additional 9 connections, and so a power plant-sized future demonstration is technically feasible.

PLANNED DEPLOYMENTS

Tide Tec

Over the last year Tidetec has completed its model turbine, and although the turbine needs some final adjustments before it can be built in a full scale version, the company considers the proving of the mechanical and hydrodynamical aspects of the turbine to be completed. New is that the design of the periphery is changed to a dry-running sealed generator.

The company has taken some significant steps in 2017: Tidetec have secured the IP in Norway through a new patent, which currently has moved further to a PCT application (European and worldwide patent). This patent is to protect the IP of the "rolling turret", which is fundamentally different from the original Tidetec concept. The application is currently also delivered in Europe (EPC), and a conclusion on this application will be given during 2018.

Tidetec have proven the technology further with a functioning model turbine, tested at TUM in Munich. Tidetec have established contact with Atlantis, who has invited the company to tender for the Wyre barrage project. A consortium consisting of Rainpower, EPCI company, Zhefu (Chinese turbine manufacturer) is thus being developed in order to bid for the tender.

Havkraft

Havkraft AS is working in close relation with HydroWave AS in a common bid to commercialize the technology. Together, the companies are providing local energy from wave power with Guarantees of Origin; either directly as electricity in hybrid with batteries, or through Hydrogen storage.

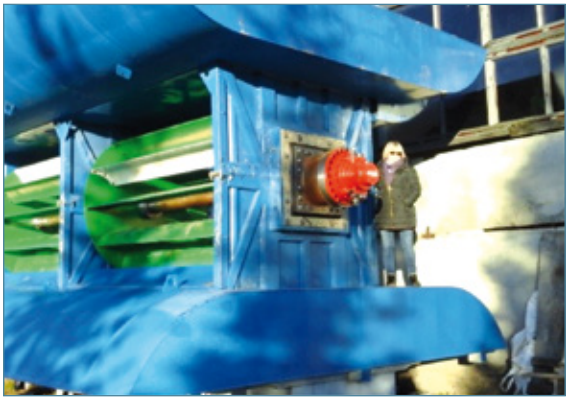
The prototype testing of the Havkraft Wave Energy Converter (H-WEC) in real sea environment at Stad was completed in 2015. Moreover, the first commercial contract was signed in 2017 with Ålesund-based Uksnøy & Co, for the replacement of diesel fuels directly on offshore installations: A low hanging fruit for this powerful, patented and flexible technology. Both companies are headed by founder, inventor and main shareholder Geir Arne Solheim.

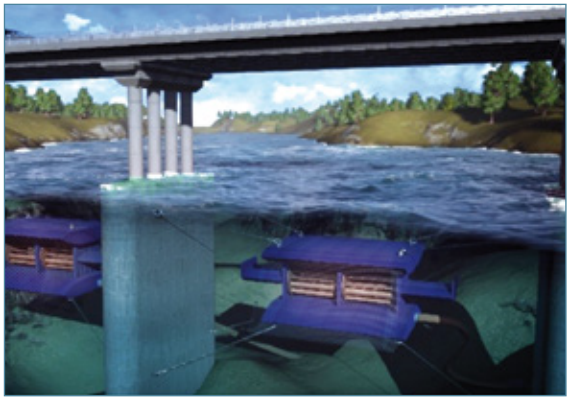
The Norwegian Prime Minister, Erna Solberg (left), visited Havkraft/HydroWave to get more information on their wave power technology in Florø, 7 November 2017. The solution has been lifted up by Innovation Norway, amongst others. The ship model Geo Barents is demonstrating a hybrid wave power system on the slip side. Present to show the PM were Geir A. Solheim (middle) and Øystein Uksnøy (right).

Deep River

Deep River has continued the development on an easily deployable “Drop & Go” power plant, weighing 100 kg. This micro plant will be able to produce from 1 kW to 20 kW, and may be hooked up through a battery-pack. The Drop & Go system is ready for a commercial market as of 2016.

Deep River aims at an international market, seizing on the opportunity for local power production, off-grid solution, energy storage and easy grid connection. The technology has been developed in close collaboration with Norwegian and international universities, as well as with international suppliers and developers.





RELEVANT NATIONAL EVENTS

The Ocean Energy Bill, which regulates renewable offshore energy production, entered into force on 1 July 2010. According to this new legislation, licenses to build offshore wind, wave and tidal farms in certain far shore geographical areas cannot be given without a prior governmental process where suitable areas are identified.

As a follow up to the Ocean Energy Bill, the Norwegian Water Resources and Energy Directorate (NVE) identified 15 areas that could be suitable for large scale offshore wind power. More detailed “strategic consequence assessments” was finalized late 2012. In the 2016 white paper on energy policy (Meld. St. 25 2015-2016), the areas pointed out by NVE are mentioned as potentially delivering 50 TWh, fully developed. With the Parliamentary debate on the national budget for 2018, came a call from Parliament for the Government to open areas for licensing. The Ministry of Petroleum and Energy said at the end of 2017 that it will designate one or two areas that will be opened for licencing of commercial scale ocean energy production “as soon as possible”.

PORTUGAL

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

Portugal has a National Ocean Strategy (NOS 2013-2020) to develop its maritime potential, based on knowledge, technological progress and utilisation of its entire maritime territory. In 2017, the Portuguese Government approved the Industrial Strategy for Oceanic Renewable Energies (EI-ERO) with a set of measures for wave energy and floating offshore wind. This follows the Resolution of the Council of Ministers in 2016 (no. 15/2016, of 9 March) which established a Working Group, coordinated by the Minister of the Sea, whose mission was the presentation and promotion of a public discussion of a model for the development of offshore energy in Portugal, with the objective of boosting investment in demonstration projects and pre-commercial projects in this area, with strong involvement of the industry. In this context, the report "Roadmap to an Industrial Strategy for Oceanic Renewable Energies" was under public discussion between November 2016 and March 2017. A set of actions are proposed, among which the implementation of policies and financial support to accelerate the competitiveness of the Portuguese industry in specific niches of the ocean energy value chain, the financial support for the offshore electrical cable in Viana do Castelo (for the Windfloat 25 MW floating offshore wind project), the creation of a pilot zone in the same region and the development of innovation centres in ports acting as accelerator hubs of ocean energy technologies, as well as linking industry and science.

PUBLIC FUNDING PROGRAMMES

The Portuguese Government has created a new mechanism "Fundo Azul" (Blue Fund) to develop the ocean economy, promote scientific work on the oceans and environmental protection. Tenders were launched in 2017 to award funds to projects from "new entrepreneurs of the sea" and for promotion of renewable energies.

RESEARCH & DEVELOPMENT

WavEC Offshore Renewables

WavEC is a private non-profit association, currently with 12 associates (private and public), and devoted to the development and promotion of offshore energy utilization thorough technical and strategic support to companies and public bodies. WavEC team is composed by 20 specialists with a broad range of experience on ocean energy, including both the technical (numerical modelling, wave resource, monitoring, technology) and non-technical (economic models, environmental and licensing, public policies, dissemination) issues.

WavEC is a founding member of the European Ocean Energy Association (OEE) and associate member of the European Energy Research Alliance.

WavEC is coordinating the European funded project WETFEET, running since 2015, and has been further involved in a number of R&D projects mainly funded by the European Commission and by the national Foundation for Science and Technology, through the funding programme Oceanera-net.

Three new projects funded by the European Commission programme Horizon2020 were approved by the end of 2017, to start in 2018:

- MEGAROLLER: a 3-year project to develop and demonstrate a Power Take-Off (PTO) for wave energy converters, led by the Finnish developer AW-Energy which has been developing a project in Portugal.
- SEA-TINTAN: a 3-year project to develop and demonstrate a Power Take-Off (PTO) solution based on the existing Wedge Global W200 PTO prototype, led by the Spanish developer Wedge Global.
- DTOceanPlus: a 3-year project led by Tecnalia to develop and demonstrate an open source suite of design tools for the selection, development, deployment and assessment of ocean energy systems (including sub-systems, energy capture devices and arrays).

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 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.

Model testing of the twin-rotor air turbine (left) at IST; biradial turbine prototype installed at the OWC-breakwater, Mutriku, Spain (right).

IDMEC/IST is a partner in the WETFEET project (European H2020 programme); in 2017, their involvement concerned mainly the dry-testing of the high-efficiency twin-rotor radial-inflow self-rectifying air turbine at IST. IDMEC/IST is also 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 prototype was supplied by Kymaner, and, after dry-testing at IST, was installed at one of the OWCs of the Mutriku breakwater (Basque Country, Northern Spain), where it has been operating under real sea conditions since June 2017. In 2018, the turbine will be installed on the spar-buoy OWC of the Spanish company Oceantec, for testing at Bimep test site (Northern Spain).

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 has 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).

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

During 2017 efforts were initiated to build a structured plan for developing testing infrastructures for different TRLs, providing technical support to developers, in order to attract projects to Portugal. The following test sites were proposed:

Viana do Castelo Pilot Zone – Offshore Farm Site

Following the Governmental decision in December 2016, a Pilot Zone for offshore wind and wave energy will be settle in Viana do Castelo (Northern coast of Portugal), managed by REN (the Portuguese TSO), where a first 25 MW WindFloat farm will be deployed in 2019. A 17 km electrical cable and an onshore electrical substation will allow other offshore energy technologies to be demonstrated. This site, located in depths between 85 and 100m, is currently being licensed for the installation of the Windfloat Atlantic Project. The Portuguese Pilot Zone created in 2010 at São Pedro de Moel has moved to this area. Currently the electrical infrastructure (onshore substation + static cable) is being designed and a tender has been launched by REN for a 200 MW cable.

Aguçadoura testing site - Offshore Test Site

This is a 4 MW grid connected offshore testing site offshore Póvoa de Varzim, for wave and offshore wind, which belongs to EDP and EFACEC. The test site, in 50 m water depth, is composed by a 6 km 4 MW offshore electrical cable, an onshore monitoring station and an onshore electrical substation. Previous devices tested at the Aguçadoura site comprised: the AWS wave power device (2000-2004), the Pelamis wave farm (2007 – 2008) and the WindFloat floating wind turbine (2011 - 2016).

Sines – Ocean Technology Incubation Centre

Sines Port Authority, WavEC and other Portuguese and Dutch companies have recently signed an agreement to develop a test centre for partial scale non-grid connected wave energy prototypes. A Letter of Intent signed in October 2017 foresees consenting of this infrastructure within the Port jurisdiction.

Peniche – Ocean Technology Centre

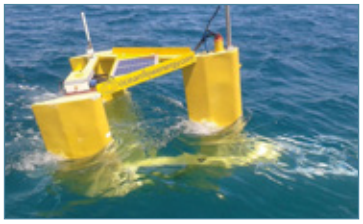
The Peniche Shipyard with a number of entities have been preparing a proposal to develop an ocean technology centre at Peniche Shipyard with a focus on the development and study of materials and its interaction with the ocean environment.

OPERATIONAL PROJECTS

In 2017, **Pico Plant**, on the Island of Pico, Azores, was still running, but a decision has been taken to decommission the plant which has achieved 10 years of continuous operation. It is a shoreline OWC (Oscillating Water Column) wave energy pilot plant (www.pico-owc.net) built in 1995-1998 with support from the European Commission. It is operated by WavEC and during the last decade, it has been used as a research and training facility.

Pico Plant, Azores

The UK-based tidal energy developer **Oceanflow Energy** has been testing their Evopod E1 unit at Ria Formosa, a coastal lagoon in the south of Portugal. This demonstration project at 1:10 scale has been conducted by the Marine Offshore Renewable Energy (MORE) team from the University of Algarve as part of European funded project SCORE whose goal is to examine the behaviour of small scale tidal current turbine in a shallow water estuarine environment. The project started in April 2016 and will run for 3 years.



Evopod E1 device (CIMA-MORE)

PLANNED DEPLOYMENTS

WaveRoller

During the year 2017, AW-Energy made significant progress in its commercial roll-out as the company secured an EPC agreement with Wärtsilä in September. Wärtsilä will now be selling WaveRoller technology on a turn-key basis throughout the life cycle. Another milepost was reached in August when Lloyd's Register issued WaveRoller the first Design Appraisal Certificate to be awarded in the wave energy industry. AW-Energy has also been working with external partners, such as WavEC Offshore Renewables and Queen's University Belfast, to further research and develop its product. AW-Energy's FOAK pilot project site in Peniche, Portugal, is now fully licensed. In addition, 8 MWA grid capacity is secured for commercial instalment and being prepared for customer use.

OTHER RELEVANT NATIONAL ACTIVITIES

WavEC organised a seminar on marine renewable energies on 11 November 2017. The event had 100 participants and counted with the presence of the Portuguese Minister of the Science and Technology.

IST and WavEC have been involved, since 2013, in the EUREC master course in Renewable Energy, offering a one-semester specialization in ocean energy. This took place from February to May 2017.

SINGAPORE

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

Singapore has set a national target for reducing its greenhouse gas emissions intensity by 36% by 2030, compared to 2005 levels. Singapore is also working towards stabilising its emissions with the aim of peaking around 2030 (Singapore Climate Action Plan, 2016). This makes improving energy efficiency as Singapore's key strategy to reduce greenhouse gas emissions, and plans have been made to expand the scope of current initiatives across all sectors especially the power generation sector (NCCS, MEWR & MND, 2016).

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 mainly comes in the form of funding for Research & Development to develop capabilities within the industry.

PUBLIC FUNDING PROGRAMMES

More than S$800 million public funding has been set aside by the Singapore Government for research in energy, water, green buildings and addressing land scarcity, of which S$140 million is allocated for research into clean energy technologies under the banner of the Energy Innovation Programme Office (EIPO) (EDB, 2015). Ocean renewable energy has been identified as one of the prominent alternative energy by Energy Research Institute @ NTU (ERI@N) specifically towards remote coastal and island regions as part of its strategic research interests. The Government also welcomes clean technology companies to use Singapore and its islands as a 'Living Lab' to testbed and demonstrate innovative solutions before scaling up for the rest of the world. In 2017, the Singapore Economic Development Board (EDB) also secured investments from six clean energy companies worth $500 million for next five years (EDB, 2017).

RESEARCH & DEVELOPMENT

ERI@N, supported mainly by the EDB, focuses on the areas of sustainable energy, energy efficiency infrastructure and socio-economic aspects of energy research. Its mission is to be a centre of excellence for conducting advanced research, development and demonstration of innovative solutions, which have both regional and global impact. The Institute has considerable expertise and strength in areas of offshore energy, which includes wind, wave and tidal energy and complementary technologies, such as energy storage, micro grids, and smart energy systems, and collectively provide an integrated set of expertise from materials design & synthesis, device fabrication and modelling, and systems integration and optimization.

ERI@N's Wind and Marine (W&M) research programme is aimed at improving the performance, lowering costs and accelerating deployment of offshore renewable technologies specific to the tropics, where unique technology challenges exist. It advances the technology development and commercialization through early collaboration with industry. It works closely with government agencies to understand regional needs, and with local and global renewable energy firms to identify technology gaps and develop the appropriate technologies.

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

Sentosa – ERI@N Tidal Site

The Sentosa Tidal Test Site is a joint collaboration between Sentosa Development Corporation (SDC) and ERI@N, funded by the Ministry of Trade and Industry's Core Innovation Fund. This project aims to showcase tidal energy extraction as a feasible and sustainable energy generating technology in Singapore and to provide opportunities to develop local technologies to harness the energy available in the narrow channel between Singapore and Sentosa. In November 2013, ERI@N and SDC officially launched the Sentosa Tidal Test Site (NTU, 2013). Recent developments on the test site include the deployments of tidal turbines supported from the floating barges. Also, novel concepts such as anti-biofouling coatings are being evaluated for better field performance. The power developed is used for electric lighting on the boardwalk.

Floating hinged turbine support frame to house tidal turbine devices(Left), Scaled (1:3) tidal turbine in tow tank (Middle) and successful deployment of the turbine at Sentosa Test site. (Right)

ERI@N Tidal Turbine System

In the interest of promoting sustainable energy solutions to achieve energy security with reduced carbon footprint from tropical regions, the Energy Research Institute at Nanyang Technological University (ERI@N) works with international partners in developing and test bedding tidal in-stream energy systems for island conditions with micro grids architecture. Recent developments include the deployment of scaled tidal turbines supported from the floating barges. Image below shows the successful deployment of the first tidal turbine installation at PT BUMWI's woodchip factory located in the remote Pulau Amutu Besar, Bintuni Bay, West Papua, and Indonesia. The project was developed through a collaborative effort of Energy Research Institute at Nanyang Technological University, Singapore (NTU Singapore), along with Green Forest Product & Tech Pte. Ltd. (GFPT), and its exclusive supplier PT Bintuni Utama Murni Wood Industries (PT BUMWI), together with SCHOTTEL HYDRO, OceanPixel, Aquatera.

Successful development & deployment of a barge based tidal turbine by ERI@N along with its industrial partners: Schottel Hydro, Ocean- Pixel, Aquatera.

This project is one of the pioneering tidal turbine deployments in Southeast Asia and may act as a model for smaller scale energy developments in coastal areas throughout Southeast Asia. This project also shows that successful deployment of ocean renewable energy technologies could be possible through regional and international collaboration with the involvement of academic and industrial partnership. The island micro grid is currently using diesel generators to power its operations. A hybrid renewable energy solution, including tidal energy, will improve the operations of the island in terms of having a cleaner and relatively cheaper energy source. The continued monitoring of the deployed solution and of the project's

impact to GPFT and PT BUMWI's locality will be a key in scaling up such initiatives. The present test bedding effort shows that a similar approach towards adoption of ocean renewable energy is achievable to empower remote islands in the Southeast Asian region. Taking this inspiration, there is now some traction in developing similar projects in locations such as those in Indonesia, Vietnam, Malaysia, Myanmar, and the Philippines.

OPERATIONAL PROJECTS

Barge based floating tidal system

In the interest of promoting sustainable energy solutions to achieve energy security with reduced carbon footprint from tropical regions, the Energy Research Institute at Nanyang Technological University (ERI@N) works with international partners in developing and test bedding tidal in-stream energy systems for island conditions with micro grids architecture. Recent developments include the deployment of scaled tidal turbines supported from the floating barges. Image below shows the barge based tidal system which is further scalable to any site flow conditions to operate in any south East Asian country. The project was developed through a collaborative effort of

Barge based floating tidal system

Energy Research Institute at Nanyang Technological University (ERI@N) together with Schottel Hydro, OceanPixel and Lita Ocean Pte Ltd.

PLANNED DEPLOYMENTS

Renewable Energy Integration Demonstrator-Singapore (REIDS)

REIDS aims to power Pulau Semakau, an island south of mainland Singapore, which serves as a landfill, purely through renewables, including ocean energy. First of its kind in the region, the hybrid micro grid will facilitate the development and commercialization of energy technologies suited for tropical conditions that will help address the growing demand for renewable energy technologies in Asia. REIDS will integrate multiple renewables and novel technologies such as power-to-gas technologies and smart hybrid grids, and enable the development of solutions suited for small islands, isolated villages, and emergency power supplies.

REIDS Onshore: The REIDS onshore project aims to solve engineering, economic, environmental and societal energy transition challenges for off grid communities. It customizes grid science towards remote islandic needs and integrates various renewables. Technologies deployed at the test bed include solar photovoltaic, wind, tidal, energy storage, bioenergy, innovative water desalination, hydrogen production, etc. Presently, work is in progress to make the island energy self-sufficient with its renewable sources.

REIDS Offshore: The offshore renewable energy integration and demonstration (Offshore REIDS) project, also termed as Tropical Marine Energy Centre (TMEC), has been initiated by ERI@N and financially funded by the ClassNK firm (a Japanese classification society) and seeks to pave the way for establishing the world's first scaled marine renewable energy testing facility for tropical needs. In March 2015, the feasibility study for the test sites was officially launched and is expected to be completed by December 2017. Presently, an environmental impact assessment (EIA) for the test sites has been carried out to understand the impact of ocean energy system deployment on marine life and environment. The outcome of this project will be extended towards Singapore's guidelines and standards development to support

Renewable Energy Integration Demonstrator Singapore

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.

RELEVANT NATIONAL EVENTS

Workshop 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 along with code-to-code comparisons. This is likely to be a joint exercise effort concentrating on the accurate modelling and reporting of tidal energy resources. This workshop was organised and hosted by Energy Research Institute @ NTU (ERI@N), Singapore, through teleconferencing in June 2017.

Workshop on Ocean Energy in Islandic Conditions

This workshop looked at the opportunities and barriers to local adoption of ocean renewable energy in island and remote coastal areas of the Asian region from the perspective of various stakeholders and the possible solutions to address the challenge. It also tackled the crucial roles of the different stakeholders (academia, policy makers, industry and end users) that each has to play to contribute to the uptake of ocean renewable energy in Southeast Asia. This workshop was organised and hosted by Energy Research Institute @ NTU (ERI@N), Singapore in March 2017.

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

The second Asian Conference on Energy, Power and Transportation Electrification (ACEPT) was organized by Energy Research Institute @ NTU (ERI@N), as a part of Asia Clean Energy Summit (ACES), and was held in conjunction with Singapore International Energy Week (SIEW 2017) in October 2017. ACEPT 2017 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.

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

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 2017) in October 2017.

International Floating solar Symposium

SPAIN

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

No relevant changes for ocean energy strategy have happened in Spain since 2011, when the Spanish Renewable Energy Plan 2011-2020 was approved. This plan included targets for ocean energy (100 MW of installed power by 2020) however, these targets seem now difficult to achieve due to the lack of specific supporting policies for ocean energy. 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 December 9th, 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. In February 2017, the Ministry of Energy updated the retributive parameters of the electricity production from renewable energy sources in the context of the Law 24/2013 of the Electric Sector. The Mutriku wave power plant is receiving funding under this scheme which partially covers the investment already done and its operation.

In December 2017, the pre-commercial public procurement tender launched by EVE in 2014 reached to the end. This fact implies that OCEANTEC presented the results of the tests carried out in BiMEP and a “Due Diligence” that guarantees the completion of a technological level TRL6-7.

PUBLIC FUNDING PROGRAMMES

There are several R&D public funding programmes in Spain no specific for ocean energy but applicable in competition with other sectors. In addition, there are a couple of programmes more specific for ocean energy:

- OCEANERA-NET COFUND is an initiative of eight national and regional government agencies from six European countries, which has received funding from the European Union under the Horizon 2020 Programme for Research and Innovation. The participating countries / regions are: the **Basque Country**, Brittany, Ireland, Pays de la Loire, Portugal, Scotland, **Spain** and Sweden. The aim is to coordinate support for research and development in ocean energy, to encourage collaborative projects that tackle some of the key challenges identified for the sector as it progresses towards commercialisation. The project launched the first co-funded call during 2017 and approved projects are expected to start in 2018.
- The Basque Energy Agency (EVE) launched a new call of its “Demonstration and validation of emerging marine renewable energy technologies” programme in 2017. As previous calls, the programme has a budget of 2,5 M€ for a maximum of 3-year duration projects

RESEARCH & DEVELOPMENT

The **OPERA** project, funded under the H2020 programme of the European Commission, presented the main achievements and lessons learnt during the first 18 months of project implementation in October 2017 to the European Commission. The project, under the coordination of TECNALIA, is making good progress in different aspects such as open-sea operating data collection and streaming, mooring loads assessment and reduction, power take-off reliability and performance, controls algorithms for reliability and performance, applicability and extension of IEC Technical Specifications, lifetime offshore logistics and risks management, cost of energy and overall assessment. The OPERA team received a very useful feedback from the European Commission and from the experts of its Advisory Board that will help improve the implementation of the project until its completion in July 2019. The project also received the Yoshio Masuda Memorial prize for its contribution to the 12th European Wave and Tidal Conference (EWTEC17) held in September in Cork, Ireland. The prize committee decided to award the OPERA consortium as a whole, since multiple high-quality conference publications were presented by IST, Edinburgh University, Exeter University and TECNALIA to inform about the progress in the development of OWC systems. Most of the project results are public and can be downloaded from the project website: http://opera-h2020.eu

Three projects are running within the OCEANERA-NET programme with Spanish participation:

- TECNALIA is leading a consortium with other partners from Spain (Zunibal, Ditrel and Basque Energy Cluster), Portugal (WavEC), Ireland (Smartbay) and UK (ORE Catapult). The so called **RECODE** project is developing and testing cost-effective components specifically designed for reliable and sustainable delivery of ocean energy. These components comprise a safety monitoring and control device, a wave measurement buoy, an umbilical cable monitoring device and an underwater device-to-cable connector for a floating energy converter.
- IK4-Azterlan, IK4-Gaiker and Mikra Recubrimientos S.L. are working together on the **OCEANIC** project focused on the development of corrosion and fouling resistant coatings for ocean energy structures, which are being tested at BiMEP open sea test facility.
- The project **SE@PORTS** deals with the use of breakwaters for wave energy development. Breakwaters are designed to withstand wave action and promote the dissipation of wave energy at the entrance of the seaport, creating sheltered conditions for port activities. The high potential of these structures for the integration of Wave Energy Converters, due to their high exposure to ocean waves, triggered the SE@PORTS project. This project intends to demonstrate this approach is a win-win solution for both breakwaters and WEC solutions in a large extent. This project consortium is composed by INEGI, UNIVERSITY OF PORTO, IH CANTABRIA, PLOCAN, IMDC, FORUM OCEANO.

2017 brought the launch of the first call for trans-national access to European offshore renewable energy test facilities within the **MARINET2** project. This project, funded by the European Commission under the Research Infrastructure section of H2020, has the participation of 7 Spanish partners: BiMEP, CENER, CTC, EVE, IH Cantabria, PLOCAN and TECNALIA being the Marine Corrosion Test Site “El Bocal” of CTC one of the most required test facility in this first call.

TRL+ is a “Retos-Colaboración” project funded by the Spanish Ministry of Economy and Competitiveness within which BiMEP and IH Cantabria collaborate to enhance technological and scientific solutions for marine renewable energy in deep and very deep waters with a market oriented approach and supporting industry needs. This project produced a complete and useful report with the Metocean Analysis of BiMEP for Offshore Design in March 2017.

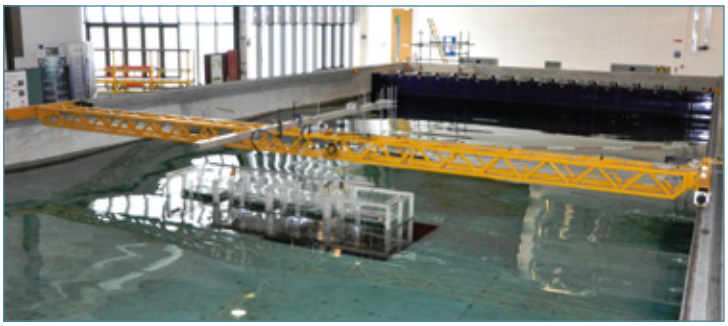
The project **ORPHEO** (2016-2018) awarded by the Spanish Ministry of Economy and Competitiveness to analyse the profitability of hybrid floating platforms to harness the wind and wave energy has continued with the activity reaching the objectives planned for 2017. This project consortium is composed by INGETEAM, ENEROCEAN, University of Cadiz, University of Malaga and PLOCAN.

Rotary Wave obtained funding of the European Union’s Horizon 2020 programme under grant agreement No 774021, within an instrument to support SMEs. The phase 1 was completed in 2017 to study the development and market uptake of an innovative system to obtain electrical energy from ocean wave resources. In addition, Rotary Wave obtained in December of 2017, an Innoglobal project to study the feasibility of implementation of a Butterfly WEC in Colombia and regional funds from IVACE (Valencian Institute of Business Competitiveness):

- CREATEC (Projects from Creation of technology-based companies) to design and develop a mechanical test bench to prove mechanical components of Wave energy converters devices,
- I+D PYME (R&D programme for SMEs), to increase the capture of power of Butterfly WEC Floats
- International programme, to develop the market study of Butterfly WEC.

During 2017, **SENER** has carried out two test campaigns in order to calibrate **SENERWave**, a software designed internally to simulate floating and fixed devices in real sea conditions, which allows the optimization of devices and arrays, as well as the calculation of project costs, including LCOE, for each location. First tests were made in the TOD tank that is located in the Universidad de Cantabria in May, while the second campaign was carried out throughout MARINET2 funds in the LiR facility in Cork, Ireland.

SENER Tank testing campaign in Cantabria



SENER Tank testing campaign in Cork

SENER has also defined and presented in several conferences a methodology to calibrate numerical models with data obtained from tank testing. These works have been made in collaboration with the Instituto Superior Tecnico de Lisboa. Finally, SENER has also finished completely the work that it has been developing for BiMEP as part of the engineering of the property contract awarded by EVE.

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The **University of the Basque Country, TECNALIA** and **BCAM** (the Basque Centre for Applied Mathematics) signed, in November 2017, a collaboration agreement between the three organisations to set up a **Joint Research Lab on Offshore Renewable Energy**. The main goal of the initiative is to increase organizations' international visibility, facilitate technology and knowledge transfer to the Basque industry, and to train future professionals for the offshore renewable energy sector. Connected to this initiative, a **Master in Offshore Renewable Energy** was established and approved by the European Commission as an Erasmus Mundus Masters Course in 2017. The Master is led by the University ofa the Basque Country in collaboration with NTNU (Norway), Strathclyde University (Scotland) and Ecole Central Nantes (France) plus the support of some 40 entities from all over Europe.

Wedge Global, jointly with **CTC** and **DEGIMA** has been developing **SMARTWEC Project**, aiming at optimizing wave energy converters point absorber type by increasing offshore reliability and energy output. The project has been funded by **SODERCAN** (Cantabria Regional Government) with the objective of developing a strategy for the supply of wave energy devices from Cantabria to the main potential markets, as well as to analyse the technical-economic viability of a wave energy farm off the Cantabrian coast.

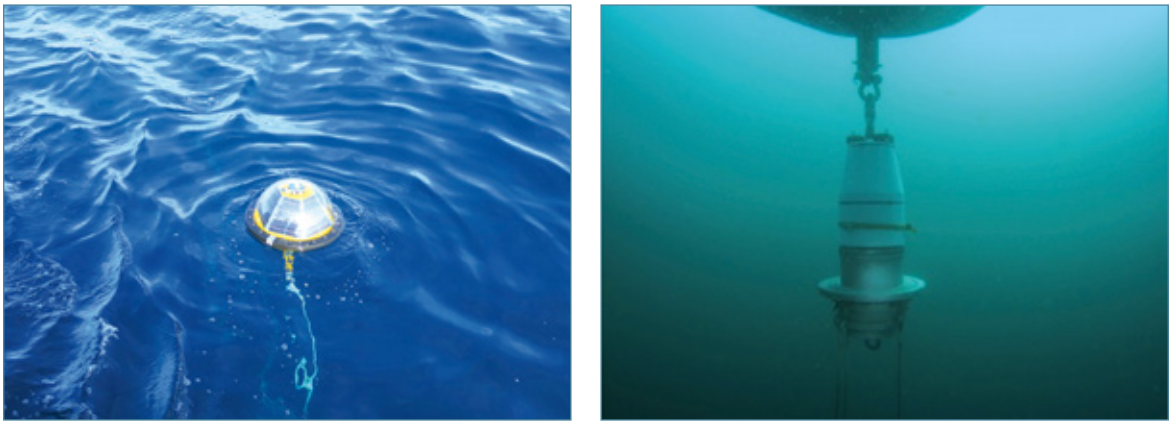
TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

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 hosts the first floating wave energy device connected to the grid in Spain (more information about this project in the next section about operational projects). Other test campaigns were carried out at BiMEP in 2017:

- the oceanographic buoy **ANTEIA**, developed by the company **ZUNIBAL**, has been tested at BIMEP obtaining very good results to collect, in real time, height, direction and period data, as well as the water temperature;
- **DITREL** has completed the survivability trials of its electric subsea connector **Konekta2** after 6 months installed at BIMEP. Konekta2 can be used to connect and disconnect different types of energy converters in the marine environment.
- I**K4-AZTERLAN** and **TECNALIA** also developed some material tests, the former under the OCEANIC project funded by OCEANERA-NET.



ZUNIBAL oceanographic buoy (left) and DITREL subsea connector (right) tested at BIMEP.

Mutriku wave power plant is the first multi-turbine wave energy facility in the world. It is integrated with the breakwater of Mutriku (Basque Country) and based on the OWC (Oscillating Water Column) principle. It has 16 air chambers and 16 sets of "Wells turbines + electrical generator" of 18.5 kW each. The plant was connected to the grid in July 2011. Two of the air chambers are prepared to test OWC components (air turbines, electrical generators, power converters and control systems). During 2017, the Portuguese company Kymaner tested its bi-radial air turbine. This novel turbine was completely designed and manufactured in Portugal, with a total investment value of circa € 1 m, and represents the culmination of the development of a patent originated in IST, protected in several countries interested in wave energy. The turbine prototype has been specifically developed and tested under the EU project OPERA. Mutriku wave power plant has also adapted its premises to better host technology developers during their tests.

PLOCAN, in the Canary Islands, 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. PLOCAN is developing the Project **REDSUB** (2017-2019), awarded by the Smart Growth Operational Programme 2014-2020 co-funded by European Regional Development Fund. This project, entitled "Electricity grid to provide support for experimenting and testing new technologies that use marine energy resources to generate electricity and for connecting technologies for observation at increasing depths", consists 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 of the maritime-terrestrial public domain reserved for the Ministry of Economy, Industry and Competitiveness. The electrical system to be installed is comprised

of medium-voltage wiring and it will be designed, fitted and sized to carry an initial maximum of up to 15 MW to shore. Most of this comprises an underwater cable, connectors and auxiliary electrical equipment (marine electrical system), which will be laid from the area of the PLOCAN reserve at sea to the sectioning and protection centre located on the coast, which will allow electrical protection between the 13.2 KV substation and the devices connected at sea. The transition of the wiring from underwater to terrestrial wiring will be done at this centre, which will connect to a shore-based sub-station to feed the electricity into the distribution grid (terrestrial electricity system). The installation of two submarine cables (5 MW/13,2 kV) started in 2017 and, depending on the weather conditions, is expected to be fully commissioned during the first semester of 2018.

OPERATIONAL PROJECTS

The **Mutriku wave power plant** has completed six years of continuous operation reaching a record of cumulative energy from waves powered to the grid of almost 1.5 GWh. As mentioned in the previous section, it is also being used as a test site for OWC components.

Following the deployment of the MARMOK-A-5 device in October 2016 by the Basque company **Oceantec** Energías Marinas and later commissioning work, the first kW was injected into the grid on 13th December 2016. Hence, the wave energy device celebrated in 2017 its first anniversary in the water at BiMEP test site. During this thrilling year, MARMOK-A-5 has demonstrated survivability in winter seas up to 12 m maximum wave height and displayed increasing availability reaching 85% at present. The research team has been able to gain 1,000 h experience in operation and maintenance as well as confidence in its power performance and mooring system robustness. MARMOK-A-5 is prepared for its second winter in a row at BiMEP. In spring 2018, it will be towed in for refitting and integration of the different innovations that have been developed in the OPERA project. Then it will be returned to it mooring site to collect more data for benchmarking. Prototype development has received funding from the Basque Energy Agency under a Pre-Commercial Procurement Contract.

MARMOK-A-5 wave energy device at BIMEP

W1 wave energy device at PLOCAN test site in the Canary Islands

UNDIGEN+ Project is a wave energy conversion demonstration project based on the industrial-scale W1 (WEC by **Wedge** technology), and it is the continuation of UNDIGEN Project, accumulating roughly 4 years, continuously in the Atlantic Ocean, of the W1 wave energy converter. The W1 system configures itself as an axisymmetric resonant point absorber with an innovative direct drive power take-off (linear generator) by applying & validating the continuous R&D activity developed in wave energy (technology development & testing) for more than ten years. The W1 system has been testing at PLOCAN site in the Canary Islands. UNDIGEN+ is a demonstration project partially funded by the Spanish Ministry of Economy and Competitiveness, led by the Spanish tech-company **Wedge Global** in collaboration with **SAES**, **CIEMAT** and **PLOCAN** which has concluded by the end of 2017.

Galicia-based **Magallanes Renovables** finished its 2 MW floating platform in April 2017 and by the end of summer was moored in the bay of Vigo where Magallanes has started its mooring and towing tests (to simulate sea currents) in order to make the set-up and check all the devices worked properly. After winter time, the platform of Magallanes will be towed to EMEC in Scotland where it will be connected to the grid to start producing electricity. This test will allow the company to validate the technology, study O&M costs and approach the market.

Magallanes floating tidal device launching

PLANNED DEPLOYMENTS

A wave-pumped desalination projects is expected to be installed in 2018 at PLOCAN. This project is promoted by the company **Tveter Power** based on a point absorber wave energy converter. PLOCAN is also expecting to see two offshore wind projects deployed by ESTEYCO (ELICAN project) and ENEROCEAN (WIP10+ project).

RELEVANT NATIONAL EVENTS

The third edition of the Marine Energy Week took place in Bilbao in the last week of March 2017. For the first time and together with Sinaval International Shipbuilding, Future Port Bilbao, and Eurosifhing conferences, four of them were celebrated under a bigger event named WMW – World Maritime Week. The conference, organized by EVE, TECNALIA and the Bilbao Exhibition Centre, brought experts from leading agents, companies, researchers and decision-makers involved in the offshore wind and ocean energy sectors. Marine Energy Week comprises international project meetings, technical visits, a poster session focused on research activities, an industrial workshop on offshore wind supply chain, an offshore wind conference, an ocean energy conference and an exhibition area integrated with WMW, including networking and B2B spaces.

The **Wave Energy Basque Country group** supported the organization of the Ocean Energy Europe 2017 conference in Nantes with a silver sponsorship.

APPA-Marina, jointly with the Naval Engineering School of Madrid organized the **third edition of the National Annual Conference** on Marine Renewable Energy in Madrid in November 2017. Test centre representatives, Government officials, researchers and industry leaders provided an in-depth coverage of the current and future industry, highlighting specific areas of growth as well as the latest technological developments in Spain. **APPA-Marina**, founded in 2006, is formed by the main Spanish stakeholders working on ocean energy and offshore wind. Its main objective is to bring together Central and Regional Governments, R&D institutions and industrial companies interested in the development of marine renewable energy.

The Spanish Association of Marine and Offshore Engineers (AINE, as it is known in Spanish) organised the 8th edition of **ENERMAR** in June at PLOCAN onshore offices in Taliarte (Telde), on the island of Gran Canaria, entitled “The sea and renewable energies: the contribution of Marine and Off-shore Engineering”. The event was attended by more than 70 professionals.

The Marine Renewable Energy working group of the Atlantic Arc Commission was created in 2010 at the initiative of Cantabria that chaired it until 2013. The Basque Government took over the presidency of the group in 2017. The creation of this group is the result of the growing interest for MRE in the Atlantic for environmental (cleaner energy) and economic (high potential, creation of jobs and growth) purposes. The aim of the group is twofold: ensure a legal monitoring in the field of MRE; bringing together the MRE stakeholders.

SWEDEN

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 percent renewable electricity production by 2040 and no net emissions of greenhouse gases in the atmosphere by 2045.

Additionally, in 2015, the Ministry of Enterprises, Energy and Communications enacted a national maritime strategy[1] 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, and there is on-going work to identify indicators for each area to track progress and its impact on the vision of the maritime strategy.

MARKET INCENTIVES

The long-term Swedish energy policy relies on economic policy instruments, including a carbon tax, international emissions trading and a renewable electricity certificate system. All these instruments provide incentives for renewable energy and do not specifically target a particular renewable electricity conversion technology, i.e. 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 large 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 2015, the Swedish Energy Agency initiated a national ocean energy programme with the aim to strengthen research and development capabilities and increase the cooperation between and within academia and industry. The programme will run for four years and has a total budget of around €5,7 million (53 MSEK).

A total of 16 projects have been provided with funding from the programme. The programme is now being evaluated in parallel with the planning of a new programme stage. The activities and priorities of the new 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[2].

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

The Swedish Energy Agency is also involved in OCEANERA-NET and OCEANERA-NET Cofund, which are collaborations between national/regional funding organisations, and EU to support the ocean energy sector and fund transnational projects.

RESEARCH & DEVELOPMENT

Swedish companies, universities and institutes were involved with several research and development projects during 2017. Below are just a few examples.

R&D of dynamic low voltage cables between the buoy and floating hub in a marine energy system

Participants: Chalmers Department of Mechanics and Maritime Sciences, CorPower Ocean AB, Seaflex Energy Systems, Waves-4Power, NKT Cables AB, Minesto and RISE Research Institutes of Sweden AB

The project started in 2015 and will end during 2018. The objective of the project is to strengthen the ocean energy sector by establishing performance and design criteria to deliver a subsea electrical cable for dynamic environments. A mathematical model for power cables with fixings will be developed to simulate the cable movements and to calculate the fatigue failure of the electrical conductor. The model will be calibrated using different variants of prototype cables which will be produced by NKT Cables and tested in field trials for typically six months at the test facility at Runde Environmental Centre in Norway. Based on the model and field tests, a method for laboratory accelerated fatigue tests will be designed, set up and evaluated.

ELASTMOOR - Elastic mooring systems for wave energy converters

Participants: University of Lisbon, Chalmers Department of Mechanics and Maritime Sciences, Seaflex Energy Systems and Waves4Power

The project is an OCEANERA-NET research project, started in 2017 and will end during 2020. 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 in Portugal and (iv) the development of constitutive models which will be implemented in an in-house mooring dynamics numerical model. The simulation tool will be used to analyse the durability of mooring systems. Reliability analysis will be used to consider the statistical variability in parameters that have an influence on fatigue life.

Direct drive generator development

Participant: Royal Institute of Technology

The project is developing a new type of linear generator of transverse flux type that is predicted to be very efficient, low-cost and force dense. A prototype is being built in the lab of the Royal Institute of Technology which is aimed to demonstrate the technology. The prototype is to be demonstrated during the Spring of 2018.

Powerkite - Power Take-off System for a Subsea Tidal Kite

Participants: Midroc, ENGIE Lab Laborelec, Minesto, Chalmers University of Technology, Queen's University Belfast, SSPA Sweden AB, AC&E, UW-ELAST AB and MoorLink Solutions AB

The project that has received funding from the European Commission started late 2015. It aims to develop a next-generation technology of tidal and ocean current power plant. During 2017, SSPA worked with the development of a more efficient turbine.

System design and development of wave power systems with centralized conversion to electricity (in a hub), and combining buoy and power take-off technologies

Participants: Ocean Harvesting Technologies AB, CorPower Ocean AB and Waves4Power

The project was funded by the Swedish Energy Agency and private investors and was completed during 2017. The objective of the project was to investigate whether hydraulic collection of power from wave energy converters to a central collection tower with gravitational energy storage and conversion to electricity can provide lower electricity production

cost than more common de-centralized systems where electricity is generated directly in the buoy. The project demonstrated that in some cases the annual power capture could be increased by 10% with a hydraulic PTO. Nevertheless, the final electric output was reduced by 5% with the hydraulic system due to higher losses. Different storage capacities in the central gravitational energy storage were also investigated.

MaRINET2
SSPA and Uppsala University are partners in the project MaRINET2 within the Horizon 2020 programme. The aim of the project is to facilitate research infrastructures for offshore renewable energy. SSPA has three major test facilities that are well suited for marine energy scale testing. Uppsala University operates the open sea wave test site Lysekil.

Testsite Skagerrak
"Testsite Skagerrak" aims to develop the opportunity for a common innovative environment that offers Swedish and international players both biological as well as technical offshore testing and demonstration sites. By combining and finding synergies in R&D activities in marine biomass, marine energy systems, underwater technology, etc., this development can be strengthened and coordinated into attractive offers. Customers are development companies, subcontractors, researchers and national and international R&D projects that can make use of the facilities. "Testsite Skagerrak" is in a planning phase to determine needs, focus areas and organizational set-up. The project is supported by the Swedish Governmental Agency for Innovation Systems (Vinnova), Västra Götaland region and Fyrbodal municipality.

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

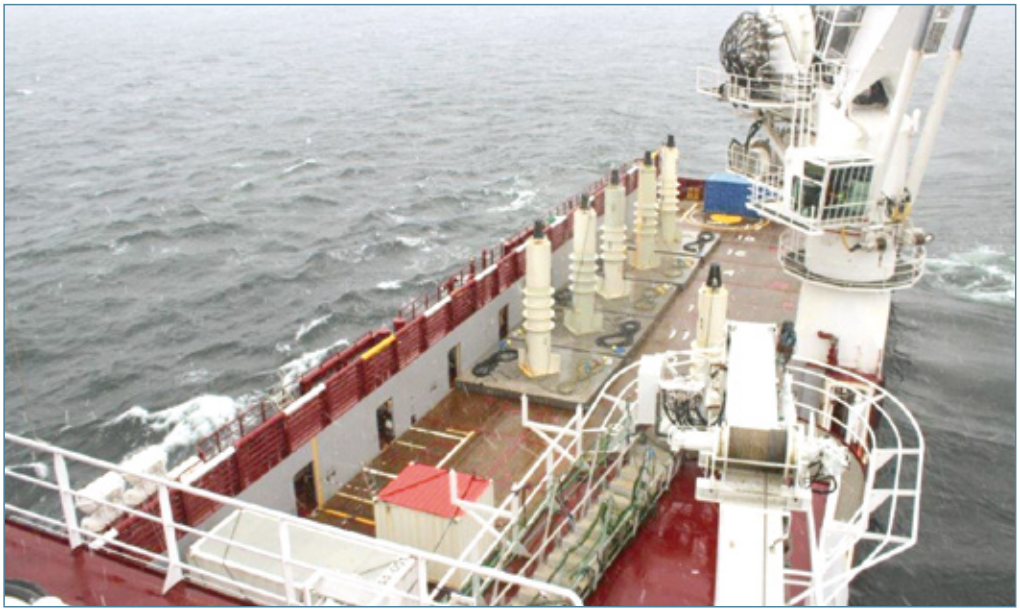
The Lysekil wave energy research test site
The wave energy research group at Uppsala University tests full scale devices and technology solutions at a research test site outside the town Lysekil at the west coast of Sweden. The test site is part of the MaRINET2 network. It has been grid connected since November 2015.
During 2017, a signal cable and a 230 V cable to the islet Klammerskären (where there is an observation tower and plans for communication equipment) were installed. Improvements in the measuring station were made. A sea based wave power plant was installed and connected to the land cable in June. A new Uppsala University wave power plant with buoy was installed and connected to dump load with dry-mate connectors.

Marine environmental studies have also been undertaken. A sonar platform with hydrophone, C-Pods and video camera were deployed to detect and track seals and fish that swim close to a WEC. Visual observations using scuba diving were made to collect data about macro fauna around the bio fundaments. Cage fishing was applied inside the Lysekil research test site and respective control areas east and west of the wave power test park to investigate macro decapods and give insight of abundance, difference in size and gender and their distribution.

OPERATIONAL PROJECTS
The only projects that are implemented in Swedish waters are the **Lysekil wave power project, Söderfors marine current project and Sotenäs project**.

Lysekil wave power site and Söderfors marine current site are operated by Uppsala University. At Lysekil, two new wave power plant installations were made during 2017. At Söderfors, a vertical marine current plant is being tested.

The Sotenäs project was initiated in November 2011 and 36 wave energy generators have been deployed along with the subsea generator switchgear. The Sotenäs project was funded by the Swedish Energy Agency, the power company Fortum and by Seabased Industry AB. The wave park was originally constructed for and delivered to the Finnish power company Fortum. In a recent agreement, Seabased will take over ownership of the wave park itself in order to continue its development.



Deployment of wave energy generators in the Sotenäs project

Waves4Power is another Swedish company demonstrating one full scale wave power device at sea; however the demonstration takes place at Runde test site in Norway. The installation was launched in February 2016 and is partly financed by the Swedish Energy Agency. On 2 June 2017, the device was connected to the grid and started delivering electricity. A couple of months after that a seminar was held for investors, development partners and local community and H. M. King Harald V of Norway helped cut the ribbon and inaugurate the WaveEL system. Due to damage to two of the mooring lines of the WaveEL buoy, Waves4Power chose to tow the buoy to Fiskåholmen in late November 2017, a month earlier than first planned. A thorough analysis of the mooring system with an assessment of what happened was initiated. The buoy, however, is intact.

PLANNED DEPLOYMENTS

The deployments by Swedish developers planned for the near future will take place outside of Sweden.

Minesto develops a technology called Deep Green that can produce electricity from low-velocity tidal and ocean currents.The technology has been tested with scale model prototypes at the company's test and demonstration facilities in Strangford Lough, Northern Ireland, since 2011. This testing continued during 2017.

In 2017, Minesto engaged in the development, manufacturing, assembling and preparation for offshore activities of the first device in commercial scale. Commissioning is expected to commence in 2018 and will take place at Holyhead Deep, 8 km outside the coast of northern Wales. Minesto has received funding from KIC Innoenergy and European Regional Development Fund through the Welsh Government.

CorPower Ocean develops a compact high-efficiency wave energy converter, inspired by the pumping principles of the human heart. In the current HiWave Stage 3 programme, a large-scale wave energy converter was taken through dry testing in a Hardware-in-the-loop rig in Stockholm during 2017. This is followed by ocean deployment at the European Marine Energy Centre's (EMEC) Scapa Flow test site in January 2018.

The project is funded by the Swedish Energy Agency, KIC Innoenergy and Wave Energy Scotland. Stage 3 demonstration is supported by best practice from EMEC in Orkney, alongside the experience from offshore power generation company Iberdrola Engineering and EDP, the University of Edinburgh and WavEC Offshore Renewables expertise in cost and performance modelling. Next step after verification of Stage 3 is planning for Stage 4 & 5 programme involving dry and ocean testing of full scale wave energy system between 2018 and 2020 followed by a first array installation 2020-2022.

CorPower's wave energy converter

Waves4Power has started the development of the Next Generation WaveEL 4.0 buoy. The aim is to replace steel in the buoy hull and acceleration tube with polymeric materials, to the extent possible. The development is on-going with the same partners as before, i.e. Siemens, Parker, NKT Cables, Petronas, SSAB and Jotun, but with the addition of Borealis AG from Austria, as a new key contributor on polymeric materials. The next generation system will utilize the same conversion system principle and mooring system that has now been proven over several trials, but simplifications will be implemented to cut CAPEX and OPEX substantially for the lifetime of the wave power system.
Cooperation with Stryvo Group in Norway to develop best manufacturing practices in combination with access to Fiskåholmen shipyard and the deep port next to the shipyard will secure cost-efficient production and material handling for the future high-volume production of WaveEL 4.0 buoys.

Seabased has signed a contract for a wave energy park in Ghana. The Ada Project was initiated in November 2014 and the first step in a large planned build-up of wave power in Ghana, off the coast of Ada, is under development. Seabased participates as main contractor and equipment supplier to TC's Energy, Ghana.

RELEVANT NATIONAL EVENTS

Annual conference in the Offshore Väst project and network, 18-19 October, in Lerum, Sweden
Several projects on wave and offshore wind energy were presented to the audience. The presentations were held by Chalmers University of Technology, RISE Research Institutes of Sweden AB, and the companies Sigma Energy & Marine, FlowOcean and Ocean Elements.

MARENER2017, 24-25 January, on WMU in Malmö, Sweden
This two-day conference had a session where several presentations on wave energy were presented. Uppsala University and Chalmers University of Technology gave a number of presentations.

UNITED KINGDOM

INTRODUCTORY NOTE

2017 has seen much development in the ocean energy sector in the United Kingdom (UK). Significant steps towards commercialisation have taken place with the completion of the first phase of two tidal stream arrays and a range of research, development and innovation projects in wave energy devices have been progressing throughout 2017. Whilst the UK has a large proportion of Europe's ocean energy resource, further reduction of technology costs is required for wave and tidal energy to compete with alternative low carbon technologies and contribute significantly to the UK's electricity supply in the run up to 2050.

Wave

In 2017 the UK's wave energy sector has been continuing to engage in targeted research and development with the purpose of moving towards convergence of design and commercialisation. Wave Energy Scotland (WES), a Scottish Government funded technology development programme has so far awarded £24.4m to 61 technology development projects in the areas of power take-offs (PTOs), novel devices, structural materials and manufacturing processes and control systems.

Tidal Stream

The UK's tidal stream sector made significant progress towards commercialisation in 2017, with a number of turbine deployments including two at array scale. The MeyGen project in Scotland's Pentland Firth has completed construction of Phase 1A of the project, involving four turbines and a capacity of 6MW. In August 2017 700MWh of electricity was generated by the MeyGen array, a new monthly record for a tidal stream project. Long-term plans for MeyGen allow for up to 398 MW within the next decade. Nova Innovation successfully deployed the third turbine of the Shetland Tidal Array in early 2017. Nova is leading the Horizon 2020 flagship EnFAIT project, which will extend the Shetland Array from three to six turbines. 2017 also saw the successful testing of the commercial scale Scotrenewables SR1-2000 floating tidal turbine, generating over 1.3 GWh at the European Marine Energy Centre (EMEC) in Orkney. Scotrenewables is leading the Horizon 2020 FloTEC project which is developing an advanced SR2-2000 turbine through a series of targeted innovations.

Tidal Range

In January 2017 a final report was published for the UK government-commissioned review of the strategic role of tidal lagoons in the UK, led by former energy minister Charles Hendry. This report supports the development of tidal lagoons, highlighting the benefits of a "pathfinder" project ahead of a wider programme. In coming to any decision on the Hendry Review, the UK Government will need to consider how this technology delivers against its priorities, as set out in its Clean Growth Strategy and Industrial Strategy. It will also need to take in account the best interests of the UK as a whole and that it represents value for money for the UK taxpayer and consumer.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The Department for Business, Energy and Industrial Strategy (BEIS) retains overall responsibility for energy policy in the UK although powers related to planning have been devolved to the governments of Scotland, Wales and Northern Ireland. The 2017 UK Government Clean Growth Strategy states that ocean energy technologies "could also have a role in the long term decarbonisation of the UK, but they will need to demonstrate how they can compete with other forms of generation."

The UK government continues to offer revenue support to a variety of renewable energy technologies through the Contract for Difference (CfD) programme. Based on top-up payments to a strike price, CfDs offer long-term price stabilisation and are awarded via competitive auctions. The second round of auctions, worth £290m per annum, opened in April 2017 with results published on 11 September 2017. Strike prices of £310/MWh for wave and £300/MWh for tidal stream were quoted for projects due to deploy in 2021/22 in the BEIS 2017 Draft Allocation Framework. Bids for wave and tidal stream CfD allocations are made in competition with other "less established technologies" in a pot that includes offshore wind and biomass. The auction results were considerably lower than the draft administrative strike prices, with offshore wind projects gaining CfDs with strike prices of £74.75 for 2021/2022 and £57.50 for 2022/23. As yet, no wave or tidal projects have been awarded a contract for difference. The Clean Growth Strategy and Budget confirmed that the £557m remaining in the former Levy Control Framework would be allocated to further CfD auctions to 2020, with the next auction anticipated for early 2019. This announcement does not mean the UK Government is ruling out support for any particular technology, including tidal, now or in the future.

UK Contracts for Difference for less established technologies: Draft strike prices and Auction results (£/MWh):

TECHNOLOGY	DRAFT STRIKE PRICES		2017 AUCTION RESULTS	
	2021/22	2022/23	2021/22	2022/23
Offshore wind	105	100	74.75	57.50
Advanced conversion technologies (with or without CHP)	125	115	74.75	40
Anaerobic digestion (with or without CHP, >5MW)	140	135	-	-
Dedicated biomass with CHP	115	115	74.75	-
Wave	115	300	-	-
Tidal stream	300	295	-	-
Geothermal	TBC	TBC	-	-

Scotland

Scotland has substantial ocean energy potential, with a third of the UK's tidal stream resources and two thirds of the UK's wave resources. It houses the flagship European Marine Energy Centre (EMEC) on Orkney and is home to Wave Energy Scotland (WES), the largest wave energy technology programme of its kind in the world.

The Scottish Government remains strongly committed to the development of a successful ocean power industry in Scotland and to maintaining its current strong lead by supporting research, development, innovation and demonstration projects. This was reiterated in the Scottish Energy Strategy, published by the Scottish Government in December 2017. The Scottish Energy Strategy also discussed the new short life industry working group, chaired by the Minister for Business, Innovation and Energy. The purpose of this working group is to agree five priorities to secure the future growth of the sector in light of changes in UK Government energy policies and EU exit.

The Scottish Government fund the Wave Energy Scotland (WES) technology programme with the purpose of supporting wave energy technology development. WES funds are committed through a series of strategically targeted innovation projects and research activities, securing intellectual property for the benefit of the industry and driving novel technology development. WES has developed a structured stage gate process for competitive development of wave technologies that provides developers with up to 100% funding through a procurement model. The programme

operates a framework for assessing the performance of technology against set standards and metrics to provide transparency and risk reduction. WES is collaborating internationally to create an agreed set of these metrics and has also embarked on a project to introduce structure to the innovative process. WES has now committed £25.4m to 61 separate research projects and is working with 171 separate organisations over 11 countries. The organisation has recently awarded funding for landscaping projects in electrical connections and moorings and foundations, which will inform any future calls. These will be followed by investigations into the benefits of very large scale wave energy converters and alternative techniques for harvesting of wave energy.

Wales

In 2017, the Welsh government announced that they had set a target for Wales to generate 70% of its electricity consumption from renewable energy by 2030. In doing so, the Welsh government aims for Wales to become a clean energy centre and actively funds marine and renewables projects. In addition to the positive message given by the Hendry review on tidal lagoons, 2017 has seen the continued development of two test sites and a number of proposals for tidal stream and tidal range projects in Wales.

Marine Energy Wales is a Welsh government supported initiative aiming to establish collaboration between developers, academia, the supply chain and the public sector. This is done through regular working groups, including sub-groups dealing with key consenting and research issues. The two ocean energy demonstration zones currently in development in Wales are supported by Marine Energy Wales. In 2017, the West Anglesey Tidal Demonstration Zone received £4.5m in EU and Welsh government funding to support the project consenting. development of a Welsh marine energy centre of excellence is also proposed, known as the Pembroke Dock Marine Project. Its aims are to convert an area of Pembroke Dock to a marine energy test area, wave energy demonstration zone and an engineering centre. The Marine Energy Test Area has received £1.9m in EU and Welsh government funding.

In 2017 Nova Innovation signed a lease for a 2 MW project at Bardsey Sound in North Wales. The Enlli Tidal Project has been awarded funding by the Coastal Communities Fund, and is currently going through the consenting process.

Northern Ireland (NI)

The NI Department of Agriculture, Environment and Rural Affairs is working to develop a Marine Plan for NI, with the aim of guiding the regulation, management use and protection of maritime regions. The report will consist of two separate sections for both the inshore and offshore regions and also include a Sustainability Appraisal. The NI Department for the Economy's 2017 Industrial Strategy also includes plans to develop a new Energy Strategy.
In 2017 DP Energy's Fairhead Tidal project submitted planning applications, with the first stage of the 100 MW tidal stream project aiming to begin construction in 2018. Regional development agency InvestNI continues to engage with the ocean energy sector with a particular focus on finding matches between the sector and the Northern Irish supply chain.

REGULATORY FRAMEWORK

The responsibilities previously held by DECC transferred to BEIS during 2016 while further work to devolve powers to the governments of Scotland, Wales and Northern Ireland went ahead. In April 2017, the Crown Estate's management duties in Scotland were transferred to the Scottish Government, as recommended by the Smith Commission and reflected in the Scotland Act 2016. Crown Estate Scotland (Interim Management) was formed on 1st April 2017. Crown Estate Scotland manages a diverse portfolio of property rights and interests including four rural estates in Scotland, around half the foreshore and the seabed out to 12 nautical miles(nm) (and renewable energy interests out to 200nm). Management of seabed rights out to 200nm around Scotland is also vitally important to being able to sustain the competitiveness of Scottish marine industries and to continue to derive wealth from the marine environment.

PUBLIC FUNDING PROGRAMS

The Knowledge Transfer Network, operated by Innovate UK, maintains a wide-ranging and up-to-date listing of funding opportunities available in the UK. By far the majority of research and development funding for energy technologies can be found in this database, available at https://www.ktn-uk.co.uk/.

UK organisations which offer funding to ocean energy projects include:

Research Councils UK
The Research Councils UK Energy Programme provides funding for a wide range of technology areas, including marine, covering research and training. It brings together investments from across the UK research councils. http://www.rcuk.ac.uk/research/xrcprogrammes/energy/

Innovate UK
Innovate UK is the UKs innovation agency and is an executive non-departmental body sponsored by BEIS. Innovate UK works with people, companies and partner organisations to find and drive the science and technology innovations that will grow the UK economy. 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 in a new research programme. WES brings together the best engineering and academic minds to collaborate on innovative projects that will accelerate the development of wave technologies and encourage the return of private investment. http://www.waveenergyscotland.co.uk

RESEARCH & DEVELOPMENT

KEY R&D INSTITUTIONS

The Offshore Renewable Energy Catapult (ORE Catapult)
The Offshore Renewable Energy (ORE) Catapult is one of seven Catapult centres set up to bridge the gap between research and commercialisation in the UK. It was established by Innovate UK to accelerate the development of innovative technology that will lead to cost reductions in the offshore wind, wave and tidal sectors. Following the merger with the National Renewable Energy Centre (Narec), the ORE Catapult now offers an integrated engineering, research and testing capability for the offshore renewable energy sector.

ORE Catapult has collaborated with over 500 industrial and academic partners in its latest financial year, including support to 134 small and medium-sized companies and participation in 35 international projects. Also in 2017, ORE Catapult launched the Offshore Wind Innovation Hub to coordinate innovation across industry, government and academia.

Supergen
The Supergen programme was set up in 2001 to deliver sustained and coordinated research on Sustainable PowER GENeration and supply. Supported by The Engineering and Physical Sciences Research Council (EPSRC) through calls and Centres for Doctoral Training, the programme has resulted in greater collaboration between academia, government and industry, the creation of new strategies and innovation programmes and provided an opportunity for international collaboration.

Supergen UKCMER
The Supergen UK Centre for Marine Energy Research (UKCMER) seeks to engage developers, industry, academia and other stakeholders to conduct fundamental and applied research that accelerates deployment of marine renewable energy. Activity across the consortium has resulted in various achievements, including:

- The population and validation of a GIS database of Scottish wave, tidal, offshore- and onshore wind resources as three year projected time series at 3 km resolution;
- The development of a wave-to-wire model of an array of wave energy converters to explore the benefits of on-board energy storage for power and speed regulation; and
- The inclusion of component reliability, operation and maintenance strategies, and predictions of device performance in the development of lifetime cost models of classes of wave energy converters.

Supergen ORE hub

In 2017, the decision was made to amalgamate the Wind Power and Marine Energy Supergen hubs into a new Offshore Renewable Energy (ORE) hub, as the two sectors were identified as having sufficient common or aligned research challenges as well as synergies in technologies to merit clustering. Consultations with the research community over the creation of the ORE hub are underway to identify a coordinated programme of multidisciplinary research ahead of Supergen Phase 4 funding in 2018.

KEY R&D PROJECTS

EnFAIT

The Enabling Future Arrays in Tidal (EnFAIT) project is a €20.2m Horizon 2020 project. The project is a partnership of nine European companies and academic partners, led by Scottish tidal energy developer Nova Innovation. EnFAIT builds on Nova's existing operational tidal power station in Bluemull Sound, off the Shetland Islands in Scotland, which was the world's first grid connected offshore array of tidal energy turbines.

The project, which began in July 2017 and will run until June 2022, was successful in winning a competitive funding award from the European Union's Horizon 2020 research and innovation programme to develop marine energy sources and demonstrate technologies in European waters. The project is a flagship initiative for the EU and marine energy, and aims to increase the commercial viability of tidal power.

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. The layout of the turbines will be adjusted to enable array interactions and optimisation to be studied for the very first time at an operational tidal energy site.

NeSSIE

The North Sea Solutions for Innovation in Corrosion for Energy (NeSSIE) project is an EU funded research project primarily focused on the research and translation of cross-industry anti-corrosion technologies in the North Sea basin (NSB) to the offshore renewable energy sectors. Led by Scottish Enterprise, NeSSIE is composed of eight partners over five countries. NeSSIE commenced in 2017 and will run for two years.

TIPA

The Tidal Turbine Power Take-Off Accelerator (TIPA) project focuses on the testing of an innovative Direct Drive Power Take-off (PTO) solution for tidal turbines, with the aim of reducing the lifetime cost of tidal power by 20%. Running until late 2019, TIPA is led by Nova Innovation and funded by EU Horizon 2020. The project includes accelerated onshore and in-sea testing of a prototype PTO with third party validation and a commercialisation strategy for selling and licensing the product to tidal energy technology developers. Project partners are SKF, Siemens, The University of Edinburgh, Delft Technical University, Wood Group and the Centre for Wind Power Drives RWTH Aachen University.

EERA Ocean Energy Joint Programme

The European Energy Research Alliance (EERA) Ocean Energy Joint Programme is coordinated by Henry Jeffrey at the University of Edinburgh. In a Joint Programme (JP) a research organisation joins institutions in other European countries to work on shared priority setting and research projects. The research themes of the EERA Ocean Energy JP are Resource, Technology, Deployment and Operations, Economics and Costs, Environmental and Socio-economic impacts, and Education and Training. An example of the work done by the EERA Ocean Energy JP includes the definition of the scope of the DT Ocean project, in which outputs from work carried out by the Ocean Energy JP fulfilled much of the requirement for background research.

ETIP Ocean

The European Technology and Innovation Platform for Ocean Energy (ETIP Ocean) project is managed by Ocean Energy Europe in partnership with the University of Edinburgh and funded by the European Commission. The key aim of ETIP Ocean is to define research and innovation priorities for the ocean energy sector and promote solutions to industry as well as European and national policy makers. In 2017, ETIP Ocean ran ten webinars and events with the purpose of encouraging knowledge exchange and collaboration within the emerging ocean energy sector.

CEFOW

The CEFOW (Clean Energy from Ocean Waves) project aims to deploy an array of three Wello Penguin wave energy converters (WECs) with improved power generation capability at EMEC's grid-connected Billia Croo wave test site. The first of these was successfully installed in March 2017. The project will demonstrate that the WECs can survive in challenging sea conditions over a period of several years. In addition, a cost reduction roadmap will be developed to bring the levelised cost of wave power closer to a commercially viable level in the near future. This project has received funding from the European Union's Horizon 2020 research and innovation programme.

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

The European Marine Energy Centre (EMEC)

EMEC is the only accredited wave and tidal test centre for ocean energy in the world, suitable for testing multiple technologies simultaneously in harsh weather conditions. The Centre offers grid-connected test berths at two test sites – one for tidal and one for wave – and also has two scale test sites allowing smaller scale devices or those at an earlier stage of development to gain real sea experience in less challenging conditions.

2017 saw EMEC host six developers: UK-based EC-OG, Nautricity and Scotrenewables Tidal Power, Ireland-based OpenHydro, Netherlands-based Tocardo and Finnish wave developer Wello. Thirty devices from nineteen companies have now been tested on site at EMEC.

Scotrenewables Tidal Power commissioned their first full commercial scale machine, the SR1-2000 2 MW at EMEC. Following first power export in March the turbine quickly set a new tidal sector record, exporting at a peak output of 2.2 MW. The test programme demonstrated the low levelized cost of energy potential of floating tidal energy with all installation and servicing operations implemented with modest multi-cat spec'd or small crew transfer vessels.

The SR1-2000 was fully grid connected over the testing period and on average supplied the equivalent of 7% of the Orkney's electricity demand when generating and up to 25% for shorter durations. By the end of 2017 the turbine had generated over 1.3 GWh. Scotrenewables are also working on the next iteration of their technology – the SR 2-2000 – as part of the Horizon 2020 funded FloTEC project.

Scotrenewables Tidal Power SR2000 (Source: Scotrenewables)

Also testing at EMEC's tidal test site at the Fall of Warness were: Nautricity, testing their contra-rotating CoRMaT tidal turbine from April to December; Tocardo Tidal Power, testing their T2 tidal turbine from February to December as part of FORESEA; and OpenHydro, EMEC's longest standing client, who continue to test a 250 kW scale version of their tidal technology at EMEC.

In 2017, EMEC welcomed back Finnish company Wello Oy who initially tested at EMEC in 2012. Wello's 'Penguin' wave energy converter (WEC) was successfully installed by Orcadian contractor Green Marine in March as part of the EU Horizon 2020 funded CEFOW project, generating electricity into the national grid in April. The Penguin has remained on site since March, surviving numerous storms including wave heights of up to 18.7 m experienced during storm Caroline. As part of CEFOW, Plymouth and Exeter universities completed the first set of ecological surveys, which will be repeated over the following two summers to monitor the cumulative impact of multiple WECs on the seabed habitat and associated ecosystem. A further two Penguin WEC's are due to be installed at EMEC over next two years as part of the CEFOW project to demonstrate a wave energy array.

Green Marine install Wello Penguin at EMEC wave test site at Billia Croo (Credit Colin Keldie, courtesy of CEFOW)

Aberdeen-based engineering company EC-OG tested their Subsea Power Hub (SPH) system from April to November 2017 at EMEC's Shapinsay Sound scale test site. The SPH combines a tidal energy convertor coupled directly to a lithium based energy storage system, and has been designed to provide power to various subsea applications.

Wave Hub

Wave Hub is a pre-installed grid connected site approximately 10 nautical miles (16 km) off the north coast of Cornwall for the testing of large scale offshore renewable energy devices. The site has a Section 36 electricity consent and holds a 25-year lease for 8 square kilometres of seabed divided into four separate berths. Wave Hub is owned by BEIS and operated by Wave Hub Limited. In 2016 Seatricity installed their Oceanus 2 wave converter at Wave Hub and Carnegie Clean Energy confirmed that it intends to develop a 15 MW array of the CETO 6 wave energy converter at the Wave Hub site, planned to be installed in 2018. In 2017 GWave secured a marine licence for the installation of its 9 MW wave energy device, which is planned to be installed in 2018.

OPERATIONAL DEPLOYMENTS

MeyGen

The MeyGen array, operated by Atlantis Resources in Scotland's Pentland Firth, expanded the array to a capacity of 6 MW in 2017, completing phase 1A of the project. In August 2017 700 MWh of electricity was generated by the MeyGen array, surpassing 1,000 MWh of generation onto the grid since project commencement. Funding has been secured for another 6 MW of installed capacity in phase 1B. Full capacity across all phases is to be up to 398 MW.

First turbine MeygGen deployment (Source: Atlantis Resources)

Nova Innovation Shetland

In 2017 Nova successfully deployed the third 100 kW turbine of the Shetland Tidal Array, installed off the coast of Shetland, Scotland. The EnFAIT project will extend the array from three to six turbines and up to 600 kW.

Nova M100 tubine, installed in the Shetland Tidal Array (Source: Nova Innovation)

PLANNED DEPLOYMENTS

EMEC

The FORESEA and MaRINET 2 calls in 2017 instigated a resurgence of wave and tidal developers planning test and demonstration projects at EMEC in the course of 2018. These include CorPower, Laminaria and Magallanes.

Fairhead Tidal

DP Energy continue to progress through planning and consenting processes with a view to install a tidal stream array at Fairhead in Northern Ireland. The first phase is to involve 4 to 6 turbines with a capacity up to 10 MW and is planned to begin construction in 2018. The full scale array is likely to be in the region of 100 MW capacity.

West of Islay Tidal Park

DP Energy was granted consent in June 2017 for 30 MW of tidal energy development.

Westray South

DP energy took over the lease for the 200 MW SSE site and are looking to update the scoping for this development.

Katanes Floating Energy Park, Dounreay, Caithness

A floating wind/wave development 2.3 km off Dounreay in Northern Scotland Each floating semi-submersible platform would host a single wind turbine of between 5 and 8 MW and wave energy convertors of between 2 and 3.6 MW capacity, deployment would be split into two phases. A screening opinion was issued in 2017 and an application is expected in 2018.

Brims

Open Hydro have a 200 MW application submitted and being considered for a tidal development on the north side of the Pentland Firth.

Scotrenewables Lashy Sound

Scotrenewables Tidal Power are applying for consent to deploy a 10 MW array at Lashy Sound in Orkney, Scotland. This array will make use of Scotrenewables' floating tidal turbine concept.

Swansea Bay Lagoon

Tidal Lagoon Power Ltd. have plans to construct a 320 MW capacity tidal lagoon scheme in Swansea Bay, Wales. A Development Consent Order was awarded in 2015 and their application for a Marine Licence is currently being assessed by Natural Resources Wales.

Carnegie Wave Hub

Carnegie Clean Energy has entered an agreement to install a 15 MW array at the Wave Hub site in Cornwall, England, using their CETO 6 wave energy converter. Stage one commissioning is currently targeting 2018, to be followed by 12 months of operation.

Enlli Tidal Project

Nova Innovation has signed an Agreement for Lease with the crown estate to develop a 2 MW project in Bardsey Sound, North Wales. The project is currently going through the consenting phase.

USA

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

In 2017, the U.S. Department of Energy (DOE) Water Power Technologies Office's (WPTO) Marine and Hydrokinetic Program solicited a second request for information from stakeholders to refine the draft National Strategy for Marine and Hydrokinetics. This Strategy has been developed and refined through multiple rounds of feedback and discussion with industry, academia, government staff, and other stakeholders. The WPTO Strategy nominally covers the time-period from present to 2035, but it is intended to be updated every 4-5 years to reflect changes in research needs, priorities, and challenges faced by the industry.

In its current form the draft WPTO Strategy consists of a vision, DOE-centric mission, set of core challenges that currently inhibit the development of the U.S marine renewable energy industry, and various approaches that the Department believes are necessary to address the challenges. An overview of the draft WPTO strategy is presented below.

Currently, the vision identified in the Strategy is for "A U.S. Marine and Hydrokinetic (MHK) industry that expands and diversifies the nation's energy portfolio by responsibly delivering power from ocean and river resources". The WPTO mission that supports this vision is to "Conduct early-stage research to further the development of transformative, reliable, and cost-competitive MHK technologies and reduce critical deployment barriers."

The draft Strategy identifies four main challenges facing the marine renewable energy industry. These challenges include: (1) the unique and complex engineering issues faced in designing devices that can efficiently convert dynamic marine resources into usable energy; (2) the related but distinct difficulties of reliably deploying and operating marine renewable energy systems in harsh marine environments; (3) lengthy permitting processes and limited access to testing infrastructure which impedes developers' ability to rapidly iterate designs; and (4) limited information developed or available on the technologies and potential markets, along with undeveloped supply chains.

These challenges illustrate why the development of commercial marine renewable energy technologies is complicated and also highlight why high-risk, early-stage research and development is necessary to catalyze innovation. Methods of approach are presented to address each of these challenges (see summary figure below), along with associated categories of activities which the DOE intends to support over time.

CHALLENGES			
DIFFICULT ENGINEERING	**INSTALLING AND OPERATING RELIABLE SYSTEMS**	**PROLONGED DESIGN AND TESTING CYCLES**	**TECHNOLOGY / MARKET INFORMATION AND SUPPLY CHAINS**
APPROACHES			
Drive **innovation in components, controls, manufacturing, materials and systems** with early-stage R&D specific to MHK applications Develop, improve, and validate numerical and experimental **tools and methodologies needed to improve understanding of important fluid-structure interactions** **Improve MHK resource assessments and characterizations** needed to optimize devices & arrays, and understand extreme conditions Collaboratively **develop and apply quantitative metrics** to identify and advance technologies with high ultimate techno-economic potential for their market applications	Validate performance and reliability of systems by **conducting in-water tests of industry-designed prototypes** at multiple relevant scales Improve methods for safe and cost efficient **installation, grid integration, operations, monitoring, maintenance, and decommissioning** of MHK technologies Support the development and adoption of **international standards** for device performance and insurance certification **Evaluate current and potential future needs for MHK-specific IO&M infrastructure** (vessels, port facilities, etc.) and possible approaches to bridge gaps	**Enable access to world-class testing facilities** that help accelerate the pace of technology development Work with agencies and other groups to **ensure that existing data is well-utilized and identify potential improvements to regulatory processes** and requirements Support additional scientific research as needed, focused on **retiring or mitigating environmental risks** and reducing costs and complexity of environmental monitoring **Engage in relevant coastal planning processes** to ensure that MHK development interests are equitably considered	Provide original research to assess and **communicate potential MHK market opportunities**, including distributed and alternate applications (e.g., desalination, powering subsea sensors, charging for underwater vehicles) **Aggregate and analyze data on MHK performance and technology advances**, and maintain information sharing platforms to enable dissemination Support the **early incorporation of manufacturing considerations / information into design processes** **Leverage expertise**, technology, data, methods, and lessons **from the international MHK community and other offshore scientific & industrial sectors** (e.g., offshore wind, oil and gas)

Approaches to Address MHK Development Challenges in Draft U.S. Dept. of Energy MHK Program Strategy

NATIONAL LEGISLATION

In May 2017, five U.S. Senators introduced a piece of legislation set to increase domestic production of renewable energy from ocean waves, tides, and currents. The **Marine Energy Act** would reauthorize the DOE's marine renewable energy programs from 2018 through 2022. The bill also directs DOE to research ways of building a stable marine energy supply chain in the United States, as well as ways of harmonizing marine energy development with ocean navigation, fisheries, and critical infrastructure such as undersea cables. The bill also includes funding authorization for the national marine renewable energy research centers. The bill is currently under deliberation.

MARKET INCENTIVES

Clean Renewable Energy Bonds (CREBs) are a market incentive for marine renewable energy developers. CREBs are tax credit bonds, the proceeds of which are used for capital expenditures incurred by governmental bodies (including states and municipalities), public power providers, or cooperative electric companies for a qualified renewable energy facility, marine renewables included. The bondholder receives federal tax credits in lieu of a portion of the traditional bond interest, resulting in a lower effective interest rate for the borrower. The issuer remains responsible for repaying the principal on the bond.

At the state level, **Qualified Energy Conservation Bonds** (QECBs) are another incentive program that may be used by state, local and tribal governments to finance certain types of energy projects. QECBs are similar to CREBS, but are not subject to a U.S. Department of Treasury application and approval process. With QECBs the borrower who issues the bond pays back only the principal of the bond, and the bondholder receives federal tax credits in lieu of the traditional bond interest. The tax credit may be taken quarterly to offset the tax liability of the bondholder.

Marine renewable energy technologies are an eligible energy resource under numerous states' **Renewable Portfolio Standards** (RPS) and voluntary renewable energy goals. This market-based mechanism requires utilities to source a percentage of their electricity from renewable resources. As of this writing, 29 states have RPS in place and eight states have voluntary renewable energy standards or targets.

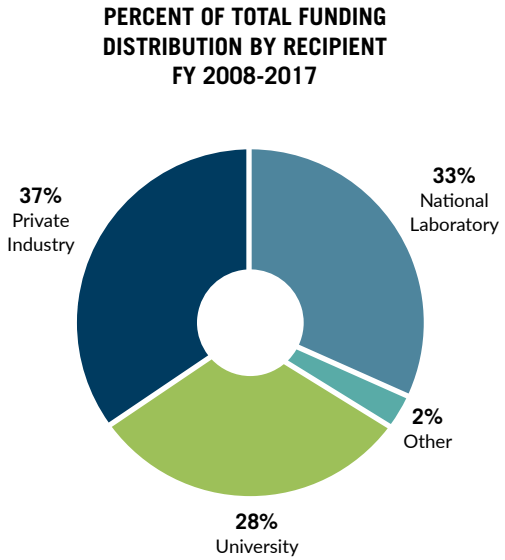
Many states also have Public Benefits Funds (PBF) which are a state-level market support mechanism designed to provide continued support for renewable energy resources, energy efficiency initiatives and low-income energy programs. The incentives for each PBF varies by state. MHK technologies can also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

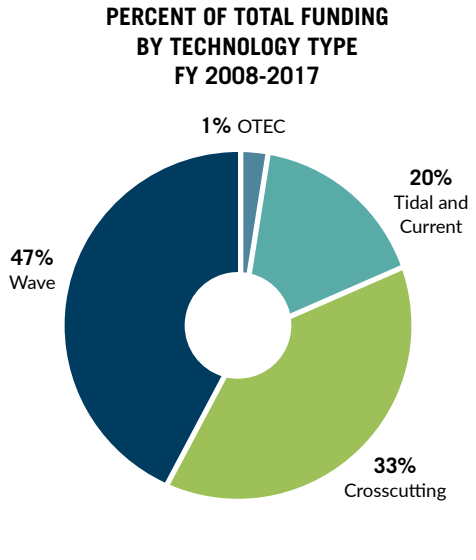
PUBLIC FUNDING PROGRAMS

Department of Energy Water Power Technologies Office (WPTO) Marine and Hydrokinetic Program

Because marine renewable energy is an early stage market with limited incentives for investment, the WPTO has a clear role in expediting the development of innovative marine renewable energy technologies. The WPTO makes investments that support key technology innovations, mitigate risks, and assist the private sector in creating a robust U.S. marine renewable industry by providing funding and technical assistance. WPTO funds research in four main topic areas: (1) marine renewable energy system design and validation; (2) testing infrastructure; (3) environmental monitoring and instrumentation development and research; and (4) resource characterization. Work in each topic area provides the industry with fundamental tools, research, and innovations that tackle specific challenges hindering development. Since 2008 the WPTO has provided funding for 228 projects which has been split roughly equally among private companies, universities, and the national labs. The bulk of WPTO funding to-date for marine renewable energy has been allocated towards wave energy research (see charts).

Federal funding for the WPTO has maintained an upward trend since fiscal year (FY) 2013. The WPTO's FY 2017 annual budget for was funded at $59 million—a 33% increase from FY 2016. The budget for FY 2018 is currently under deliberation. More information on WPTO can be found at: Water.energy.gov





Developers can seek DOE funding through several different competitive funding mechanisms. F**unding Opportunity Announcements** (FOAs) are competitive grants for industry, academic, or national laboratory to form partnerships in conducting research and testing. Some FOAs are available to international applicants. **Small Business Vouchers** (SBV) provide clean energy small businesses access to the state-of-the-art facilities and experts at participating DOE national laboratories (see Research & Development Section). **Small Business Innovation Research** (SBIR) and **Small Business Technology Transfe**r (STTR) programs are methods through which federal agencies with large R&D budgets set aside a fraction of their funding for competitions among small businesses to pursue early stage research. Small businesses that win awards in these programs keep the rights to any technology developed and are encouraged to commercialize the technology. Lastly, DOE's **Technology Commercialization Fund** (TCF) leverages R&D funding in the applied energy programs, paired with private partners, to mature promising energy technologies with high impact potential.

The WPTO identifies and funds qualified projects within specific topic areas that support program objectives, depending on available funds. In evaluating all proposals for new energy developments or new adaptations of existing technology, the 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

As an example of a recent FOA, in June 2017 the WPTO announced up to $12 million to support the development of innovative technologies capable of generating reliable and cost-effective electricity from U.S. water resources. This FOA had two topic areas, Topic 1: Wave Energy Converters System Advancement; and Topic Area 2: Marine Renewable Energy Technology Development as an open topic. There were four awards in total. AquaHarmonics and California Wave Power Technologies were each awarded funding to advance their designs and conduct open water testing under Topic Area 1. Under Topic 2, Portland State University was awarded funding to develop a multistage, magnetically geared generator specific to marine renewable energy devices while ReVision Consulting will be researching accurate wave-prediction technology for WEC device controllers that can help WECs more efficiently convert energy from waves into electricity.

U.S. Department of the Navy

The Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC) continues to actively support the research and development 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. Historically, NAVFAC funds have been allocated to the Navy's Wave Energy Test Site in Hawaii, the University of Hawaii's Hawaii Natural Energy Institute, and marine renewable energy development efforts at the University of Washington, Applied Physics Laboratory.

RESEARCH & DEVELOPMENT

There are numerous universities, private companies, organizations, non-profits, and national labs 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, the WPTO has partnered with five universities to operate three National Marine Renewable Energy Centers (NMRECs). These NMRECs are:

- **Northwest National Marine Renewable Energy Center (NNMREC):** The NNMREC is a partnership between three universities in the Pacific Northwest: University of Washington, Oregon State University, and the University of Alaska Fairbanks. The **Pacific Marine Energy Center (PMEC)** coordinates access to test facilities at the three universities and develops new, open-water test sites in the region (see Open Sea Test Sites section).
- **Hawaii National Marine Renewable Energy Center (HINMREC):** HINMREC is operated by the Hawaii Natural Energy Institute at the University of Hawaii: Manoa. Its primary objective is to facilitate the development and implementation of commercial wave energy systems. HINMREC helps with the management of two test sites in Hawaii, WETS and the OTEC Test Site (see Open Sea Test Sites section).
- **Southeast National Marine Renewable Energy Center (SNMREC):** SNMREC is operated by the Florida Atlantic University. Although SNMREC has research interests in all marine renewables, it places an emphasis on those resources available to the southeastern US: ocean currents and offshore thermal energy conversion.

The 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. The WPTO partners with several of these laboratories to support R&D in marine renewable energy, examples of their research efforts are below:

- **Sandia National Laboratories (SNL):** SNL conducts research on advanced controls, simulation of marine renewable energy environmental impacts, advanced materials for coatings and construction, testing and simulation of technologies, and resource characterization.
- **National Renewable Energy Laboratory (NREL):** NREL's water power program conducts research on energy markets, grid integration, resource characterization and mapping, design and simulation, technology evaluation and validation, as well as performing full scale validation tests on systems and components.
- **Pacific Northwest National Laboratory (PNNL):** PNNL conducts research on environmental impacts, resource characterization and modelling, advanced materials and manufacturing, monitoring techniques and data gathering, and education outreach. PNNL is also responsible for implementing Annex IV under OES on behalf of the WPTO.
- **Oak Ridge National Laboratory (ORNL):** ORNL conducts research on environmental impacts of instream technology, advanced materials for coatings and construction, design for manufacturing, and assessment of stream resources.

R&D HIGHLIGHTS

- In summer 2017, ABB along with partners at Texas A&M's Advanced Electrical Machines Lab and **Resolute Marine Energy** developed and tested an integrated magnetic-gear generator. This innovative design has advanced the state-of-the-art for power take-off systems for wave energy converters. The test results of the 10-kW prototype indicated the generator could be ideal for low-speed, high-torque applications like wave energy, or even tidal and wind. The prototype was part of a DOE-funded project to research novel direct-drive generators that could eliminate hydraulic components in some wave energy power take-off systems.
- In May 2017, **NREL** completed deployment of two buoys with high-accuracy sensors to record wave and tide movement off the coasts of Oregon and Maine, areas known to be potential hot spots for marine energy development. The work is part of larger project funded by DOE, in concert with SNL and the PNNL, to analyze wave and tidal energy sites with great potential for development and gather data to validate the computer modeling tools that industry uses to design devices.
- In June 2017, **Ocean Renewable Power Company** completed full-scale testing of a specialized bearing system and associated driveline components. The research was funded by WPTO and was completed in collaboration with the University of Maine. This is the first phase of the project, future phases will center on development of a more robust electrical generator to reduce failure rates.

- In August 2017, SNL, in conjunction with the U.S. Navy, tested advanced controls on a WEC at the **Navy's Maneuvering and Seakeeping (MASK) Basin** in Bethesda, Maryland. This testing will support the Lab in control algorithm development, numerical simulation, and future model testing to increase the power output of WEC devices. The Navy's MASK Basin, used in the finals of the Wave Energy Prize, has a state-of-the-art wave maker that is capable of making precise waves for hours. This allows researchers to quickly test the converter's control systems under numerous wave conditions and see the response.
- In 2017, **NNMREC** conducted several laboratory experiments with cross-flow turbines and simulations of wave energy converters which highlighted the potential for elevated power generation from dense array configurations, particularly when machine learning is used to coordinate control strategies across the array. Also in 2017, Environmental researchers at NNMREC achieved automatic detection and classification of marine animals using an integrated instrumentation system and advanced standardized approaches for characterizing biological environments at wave and current energy sites. Core research outcomes also included direct measurements of extreme wave conditions, methods to model and mitigate debris interactions, and robotic autonomy from inspection and maintenance activities. In aggregate, this research adds to the growing suite of innovative tools and capabilities that can reduce the levelized cost of energy (LCOE) of marine renewable energy.
- The WPTO is a supporting body of the U.S. Technical Advisory Group (TAG) to the International Electrotechnical Commission (IEC) Technical Committee (TC) 114. The IEC **TC 114,** through the collaboration of 26 member countries, is developing standards that will define the international requirements for all ocean energy devices in the future, helping with certification and commercialization of devices. In 2017 the U.S. TAG held its annual meeting in Honolulu, Hawaii, the focus of which was to discuss the status on the committee's specifications. More information can be found at: http://www.tc114.us/

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

The development of comprehensive testing infrastructure is a strategic imperative for the WPTO to successfully address sector challenges. Prototype testing is essential to drive down development costs, validate models, prove reliability, and demonstrate compliance with applicable design standards.

The majority of test sites in the United States are operated by one of the NMRECs (see R&D section), other sites across the country are operated by organizations such as the Center for Ocean Renewable Energy (CORE), the University of North Carolina Coastal Studies Institute (UNC-CSI), the U.S. Army Corps of Engineers (USACE), and the Marine Renewable Energy Collaborative (MRECo) of New England.

There are twelve open water test sites that are operational, one under development, and one offshore wind site that can be used for wave energy testing. These sites can accommodate scaled prototypes to full-scale grid connected devices. An overview of each U.S. open water test site is below. More detailed information on many of these test sites can be found at the following website: https://openei.org/wiki/Characterization_of_U.S._Wave_Energy_Converter_(WEC)_Test_Sites

U.S. Navy's Wave Energy Test Site (WETS): The U.S. Naval Facilities Engineering Command (NAVFAC), in conjunction with the University of Hawaii and HINMREC, operate this site. It is a near shore ocean wave energy test site located at Marine Corps Base Hawaii in Oahu's Kaneohe Bay. The offshore site consists of three test berths: two at 60 and 80 m depths for 100 kW to 1 MW wave energy converters, respectively, and another shallow water berth at 30-m rated for devices up to 250 kW. The berths include three-point moorings and power cable connections to the local grid.

OTEC Test Site: HINMREC also assists the private sector with advancing ocean thermal energy conversion systems towards commercialization. OTEC demonstrations and studies have been conducted at the Natural Energy Laboratory of Hawai'i Authority (NELHA) facility at Keahole Point. The Center has teamed with engineering firm Makai Ocean Engineering to conduct long-term studies of corrosion and bio-corrosion of aluminum subjected to flowing seawater. This on-shore 105 kW test facility was constructed in 2011 and is still being operated by Makai Ocean Engineering.

PMEC – North Energy Test Site (NETS): This wave energy prototype test site is located approximately two nautical miles off the coast of Oregon. It has been operational since 2012 and WET-NZ was one of the first developers to utilize the site. The site can accommodate two WEC devices concurrently with outputs of up to 100 kW. This site uses the Ocean Sentinel test buoy for site and device monitoring and as an artificial electrical load for devices.

PMEC – Lake Washington Test Site: The Lake Washington Test Site is a freshwater, off-grid WEC test site suitable for prototype testing that became operational in 2012. The site is located near Seattle, WA in the northern portion of Lake Washington. The site is best suited for wave energy converter device testing. The water depth is approximately 51 m and the gently sloping bottom has a composition consisting mostly of soft mud. There are no permanent mooring systems installed and no grid-connection.

PMEC – Tanana River Test Site: The Tanana River Test Site is located near Fairbanks, AK on the Tanana River. The site can support a single floating platform located in mid-channel with an anchored mooring system rated to 50,000 pounds holding force. The average current speed in the river is 3 m/s and the site is suitable for testing from May--September of each year. Devices rated up to 10 kW are appropriate for this test site, but it is not grid connected.

PMEC – South Energy Test Site (SETS) (Under Development): The WPTO selected PMEC-SETS as the recipient of federal funding and awarded the project $35 million to design, permit, and construct the National Wave Energy Testing Facility off the coast of Newport, Oregon. In July 2017 WPTO and Oregon State University concluded detailed negotiations for the development and operation of the site. Following construction, PMEC-SETS will serve as the national test facility for evaluating full-scale WEC device performance, environmental interactions, and survivability. This site is planning to host a utility scale grid connection from shore out to four separate ocean test berths in 65-78 m water depths. It is anticipated that SETS will be permitted for testing of up to twenty WECs concurrently, which will be useful for array validation testing. The site is planning to be operational by 2021.

Camp Rilea Test Site: Camp Rilea is a military base maintained by the Oregon Army National Guard and serves as Training Center for the Armed Forces. The testing site is operated in coordination with PMEC. Camp Rilea is not an official test site, but developers have tested at this location in the past due to its wave climate and proximity to shore. This site is located approximately one nautical mile offshore in waters about 15 m deep and is suitable for testing of shallow and mid-depth wave energy converters. The site is well monitored with data buoys, but as of this writing there is no testing infrastructure available and the site is not pre-permitted.

Southeast National Marine Renewable Energy Center (SNMREC) – Ocean Current Test Facility: SNMREC, operated by Florida Atlantic University, advances research in open-ocean current systems by building the capability, infrastructure, and strategic partnerships necessary to support technology developers on the path to commercialization. Offshore of Ft. Lauderdale, the SNMREC has small-scale test berths that are used for limited duration deployments of ocean current devices. A permanent mooring, supported by a surface buoy, is used to lower prototype devices into the Florida Current from a tender vessel. Developers can perform towed testing with a support vessel or component testing using a 3 m, 25-kW horizontal axis research turbine and in-water rotor-testing platform. Long-term deployments of prototypes can be considered on a case-by-case basis. Grid-connected, full-scale test berths are under development.

The Jennette's Pier Wave Energy Test Facility: Jennette's Pier is owned by the state of North Carolina and managed by the NC Aquarium Division. The University of North Carolina Coastal Studies Institute (UNC-CSI) began a partnership with Jennette's Pier in 2004 to foster research, ocean energy device testing and monitoring, outreach, and education. Part of this partnership is the Jennette's Pier Wave Energy Test Center. The site, located near Nags Head, North Carolina, has two shallow water test berth locations suitable for scaled prototype testing. One berth is at 6 m water depth and the other is at 11 m depth, approximately 600 m east of the pier. Moorings at the berths are temporary and power output from the berths is delivered to shore via the Jennette's Pier, but there is no grid connection. Both test berths are permitted by the USACE.

U.S. Army Corps of Engineers Field Research Facility (FRF): The Field Research Facility is near the town of Duck, North Carolina (approximately 34 km northwest of the Jennette's Pier test site). Central to the FRF is a 560 m long, steel-and-concrete research pier that extends to the 7 m water depth contour. FRF researches weather, waves, currents, tides,

and beach change. The USACE FRF offers a wide range of technical and testing infrastructure support services for WEC developers. The site has small scale, shallow water wave energy resources, and can accommodate scaled devices. There are no grid connections at this site for exporting power, however grid-access is provided via a three-phase AC outlet.

Center for Ocean Renewable Energy (CORE) General Sullivan Tidal Energy Test Site: This tidal energy test site is located in New Hampshire at the General Sullivan Bridge (Little Bay Bridge) on the Lower Piscataqua River, which is a natural bottleneck. This site is considered a full-scale test site for vertical axis turbines, and can also be considered a "large-scale" test site (prototype scales of 1:3-1:5, or 12-21 m) for large diameter horizontal axis turbines. The tidal range at this area is approximately 2.5 m and peak currents of 4 knots (2 m/s) are typical. The water depth at the site is approximately 8 m. The site has a floating test platform available for use, which is of a pontoon-barge design.

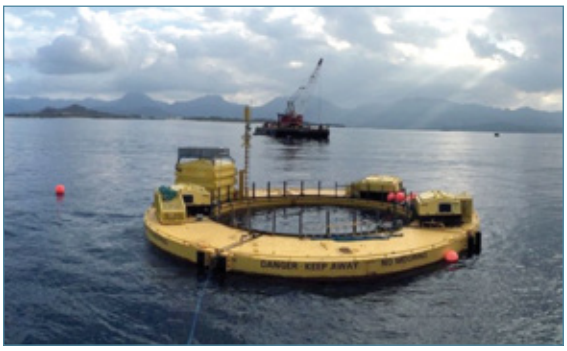
CORE AMAC Wave Energy Test Site: The AMAC wave energy test site is located at the University of New Hampshire Atlantic Marine Aquaculture (AMAC) site which is six miles from the New Hampshire coast near Durham. It covers an area of 30 acres in water depths of approximately 52 m. This site is suitable for full scale device testing. The site has a subsurface mooring system and a large feed buoy is available as a platform and a potential end user load for any wave energy extraction device, but there is no grid connection. It is fully permitted by the USACE and the New Hampshire Department of Environmental Services.

Marine Renewable Energy Collaborative (MRECo) Bourne Tidal Test Site (BTTS): BTTS is situated on the Cape Canal Railroad Bridge in Bourne, MA and was recently opened for testing at the end of 2017. Currents at this site can be upwards of 7 knots and the water flow has low turbulence and wave action. The site is close enough to shore such that cranes can be used to deploy and recover tidal devices, or alternatively serviced by a floating barge. The site can accommodate turbines up to 3 m in diameter with maximum power outputs of 100 kW.

UMaine Deepwater Offshore Wind Test Site: This test site located near Monhegan Island, about 12 miles off the coast of Maine, was created by the state legislature in 2009 and it is now one of the most extensively studied sites in the Gulf of Maine. The test site is primarily focused on the testing of offshore wind turbines, however it does allow for wave energy testing as well. The site is limited to two wave energy converters and a single subsea utility line with a maximum capacity of 25 megawatts. This site is operated by the University of Maine and has undergone multiple studies to characterize its baseline physical and ecological environments.

OPERATIONAL PROJECTS

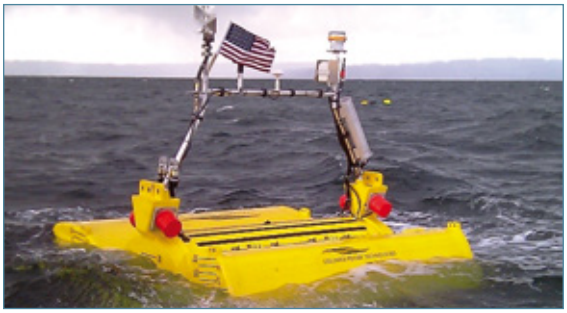
Fred Olsen: The BOLT Lifesaver, a point-absorber device, completed a one-year demonstration project at the Navy's WETS in Hawaii in April 2017. The device utilizes five power take-off units, each rated for a capacity of 10 kW. Over the length of the project, the device generated 22,364 kWh, with an average output of 3.2 kW, and the largest continuous power export lasting 200 days. This project provided excellent data on device reliability and performance, and also exposed areas for improvement in structures and materials for a more robust design.



PLANNED DEPLOYMENTS

Ocean Energy USA: The OE Buoy, an oscillating water column design, is slotted for half-scale device testing in the later-half of 2018 at the Wave Energy Test Site in Hawaii. The deployment will last approximately one year and will provide useful performance data for model validations, reliability performance, and opportunities for cost reductions.

Columbia Power Technologies (CPT): CPT is planning to test a one-third scale system of their StingRAY wave energy converter device at the Wave Energy Test Site in Hawaii in the later-half of 2018. As a precursor to this open water testing, CPT conducted testing on the StingRAY's drive train at the National Wind Technology Center (NWTC) using their state-of-the-art dynamometer in 2016 and 2017. This deployment will provide valuable reliability data as well as indicate opportunities for design improvements and optimization.



Northwest Energy Innovations (NWEI): NWEI's Azura™ is a multimode, point absorber WEC that extracts power from both the heave and surge motions of waves to maximize energy capture. NWEI has previously tested their technology in Oregon in 2012, and a half-scale device was tested with 98% availability for 19 months beginning in June 2015 at the 30 m berth at WETS. NWEI is currently developing a full scale Azura™ to be tested at the U.S. Navy's WETS in Hawaii. The proposed testing will allow to determine the energy capture matrix of a full scale device, resulting in a more accurate assessment of LCOE.

Verdant Power: Verdant's Fifth Generation Kinetic Hydropower System (Gen5 KHPS) is an axial flow current-capturing turbine system. Verdant and its partners are working on the design of a TriFrame (TF) that optimizes turbine spacing and structural requirements to allow for cost-effective installation, O&M, 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 our understanding of optimal turbine spacing and best practices for installation, maintenance, and retrieval of underwater turbines.

RELEVANT NATIONAL EVENTS

In February 2017, WPTO held its **Peer Review** Meeting in Arlington, Virginia. The purpose of the meeting was to evaluate DOE-funded water power research and development projects for contributions to DOE's mission and goals, and to assess progress made against stated objectives. Presentations from the Peer Review can be found at: https://energy.gov/eere/water/water-power-program-peer-reviews

In May 2017, Washington, DC was once again the host of Waterpower Week in Washington. This annual event brings three events under one roof: National Hydropower Association's Annual Conference, the International Marine Renewable Energy Conference (IMREC), and the Marine Energy Technology Symposium. . Information on the event, including some presentations can be found at: https://energy.gov/eere/water/articles/join-energy-department-and-national-laboratories-waterpower-week-washington

In December 2017 WPTO organized and hosted a three day Distributed and Alternative Applications for Marine Renewables Forum in Washington, DC to investigate alternative applications and markets for marine energy, other than grid scale power. The information collected from this Forum will be used in a forthcoming report on each of the potential markets and will ultimately help guide the WPTO's activities and strategy. The report will be open for public comments during 2018. https://energy.gov/eere/water/articles/marine-energy-technologies-can-meet-energy-needs-other-ocean-industries

Appendix 1

MEMBERSHIP OF THE EXECUTIVE COMMITTEE

CABINET 2017

CHAIR 2017 - 2018

Mr. Henry Jeffrey
The University of Edinburgh
United Kingdom

VICE-CHAIR (Jan – Oct 2017)

Mr. Jose Luis Villate
TECNALIA
Spain

VICE-CHAIR (Since Nov 2017)

Mr. Yann-Hervé De Roeck
France Energies Marines
France

VICE-CHAIR (Since Nov 2017)

Dr. Annie Dallman
Sandia National Laboratories
USA

SECRETARY

Dr. Ana Brito e Melo
WavEC
Portugal

DELEGATES

COUNTRY	DELEGATE	ALTERNATE
Belgium	Dr. Ludovic Mouffe Federal Public Service Economy	Prof. Julien de Roeck Ghent University
Canada	Mr. Ghanashyam Ranjitkar Natural Resources Canada	Mrs. Monika Knowles Natural Resources Canada
China	Mr. Peng Wei National Ocean Technology Center	Mr. Wang Ji National Ocean Technology Center
Denmark	Mrs. Hanne Thomassen Energistyrelsen	Dr. Kim Nielsen Ramboll
European Commission	Dr. Ir. Matthijs SOEDE European Commission DG Research & Innovation	Dr. Davide MAGAGNA European Commission 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. Satheesh C. Shenoi 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. Jin-Hak Yi Korea Institute of Ocean Science & Technology
Korea	Mr. Man Wook Hoe Ministry of Oceans and Fisheries	Dr. Keyyong Hong Korea Ocean Research and Development Institute
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	Prof. Craig Stevens National Institute for Water and Atmospheric Research (NIWA)	Mr. Gareth Gretton AWATEA
Nigeria	Dr. Emmanuel Olusegun Oyewo Nigerian Institute for Oceanography and Marine Research	Mr. Kola Onadipe Prof. David A. Aderibigbe FOT-K Consortium
Norway	Mr. Harald Rikheim Norges Forskningsråd	
Portugal	Dr. Paulo Justino Laboratorio Nacional de Energia e Geologia (LNEG)	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	Ms. Kubeshnie Bhugwandin Eskom Research, Testing & Demonstration
Spain	Mr. Luis Hilario Alonso Mijares Ministerio de Industria, Turismo y Comercio	Mr. Jose Luis Villate TECNALIA
Sweden	Ms. Maria Olsson Swedish Energy Agency	
UK	Mr. Trevor Raggatt Department for Business, Energy and Industrial Strategy (BEIS)	Mr. Henry Jeffrey The University of Edinburgh
USA	Mr. Tim Ramsey U.S. Department of Energy	Dr. Annie Dallman Sandia National Laboratories

Appendix 2

EXECUTIVE COMMITTEE MEETINGS

PAST EXCO 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

NEXT EXCO MEETINGS

MEETING	DATE	LOCAL	COUNTRY
34	14 – 15 June 2018	Cherbourg	FRANCE

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, within the IEA, that enable governments and industries from around the world to lead programmes and projects on a wide range of energy technologies and related issues. TCPs currently cover topics related to:

- efficient end-use (buildings, electricity, industry, transport)
- cleaner fossil fuels (greenhouse-gas mitigation, extraction, supply, transformation)
- renewable energy and hydrogen (technologies and policies for deployment)
- cross-cutting issues (modelling, technology transfer, project financing)
- fusion power (safety, physics, materials, technologies).

The 6000 experts in the TCPs work to advance the research, development and commercialisation of energy technologies. The scope and strategy of each TCP is in keeping with the IEA Shared Goals of energy security, environmental protection and economic growth, as well as engagement worldwide.

OES OCEAN ENERGY SYSTEMS

iea Energy Technology Network

www.ocean-energy-systems.org