ANNUAL REPORT

OCEAN ENERGY SYSTEMS

2016

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CHAIRMAN'S MESSAGE

MR. JOSÉ LUIS VILLATE
TECNALIA . OES Chairman 2013 - 2016

We have seen ocean energy development progressing at a slower pace than expected some years ago. A combination of high up-front costs and capital needs together with intrinsic technical challenges connected to the harsh ocean environment is probably the main reason. Nevertheless within a few years, 2016 will probably be seen as a take-off year for ocean energy: while several devices were being deployed, some governments set up firm policies to support ocean energy. For example, the Ocean Energy Forum presented a detailed plan to build up ocean energy in Europe. It went from the initial R&D all the way to the industrial roll-out, stating the importance of testing technologies in real conditions while introducing a phase-gate scheme to validate sub-systems and early prototypes.

I hope that after going through this annual report the reader will have a more positive view of ocean energy: on one hand, the country report chapter will allow us to learn about technology development and demonstration projects in a number of countries. On the other hand, the interviews with open sea test centres show an increasing interest of public bodies to bring more devices into the water to be tested in real conditions. At this point, I would like to thank EMEC in UK, FORCE in Canada, Oregon in US, Nagasaki Marine Industry Cluster Promotion Association in Japan and BIMEP in Spain for their collaboration in giving their views regarding the role of these test centres with their challenges and opportunities.

In this promising but challenging future, the OES has updated its international vision for ocean energy stating that by 2050 ocean energy has the potential to have deployed over 300 GW of installed capacity saving 500 million tonnes of CO_2 emissions. This would be good news both for our climate and also for society in general as far as economic growth and job creation, estimated by the OES in 680,000 direct jobs by 2050. Ocean energy matches perfectly with government priorities in many countries: climate change, industrial development and job creation. In this context, the OES has been collaborating with the OECD project on the Future of the Ocean Economy and a Discussion Paper examining the prospects and potential of the ocean energy sector was prepared in 2016.

Despite the general positive effect of ocean energy on climate change and other social benefits, some environmental concerns might arise when a specific project is defined. With the aim of reducing environmental and consenting uncertainties, the OES published a *State of the Science report* under Annex IV in 2016 summarising the interactions and effects of marine renewable energy devices on the marine environment, the animals that live there, and the habitats that support them. Furthermore, a report on *Consenting Processes for Ocean Energy* was also published in 2016 with 10 specific recommendations to facilitate consenting ocean energy projects after collecting information from several countries and project developers.

The OES is widening its range of activities with two new tasks launched in 2016: Task 10 about *Wave Energy Modelling* with the objective of verifying and validating numerical models used in the design and power production evaluation from Wave Energy Converters, and Task 11 on Ocean Thermal Energy Conversion to promote the dissemination and demonstration of OTEC by assessing the resource potential and state-of-the-art of the technology. In addition to these new activities, the OES is also growing with the participation of three new members in 2016: I would hereby like to welcome India, the European Commission and France to the OES family.

Before finishing my last message as Chairman of the OES, I would like to thank and congratulate all our members for the new term (2017-2022) recently approved by the IEA after the 2016 request for extension, including a new Strategic Plan for that period. I am sure that our new Chairman, Henry Jeffrey, with the essential support of the Executive Secretary, Ana Brito e Melo, will successfully lead the group to achieve all of the ambitions stated in our new Strategic Plan ensuring a better future for ocean energy.

I am looking forward to continuing my work in the field of ocean energy and to a productive on-going relationship with the OES representing Spain and serving as Vice-chair for another year. It has been a great pleasure to serve as OES Chairman for the last 4 years working with a committed, enthusiastic team and in particular with our leading light Ana.

NEW CHAIRMAN'S BIOGRAPHY

MR. HENRY JEFFREY
University of Edinburgh . OES Chairman 2017 – 2018

Henry Jeffrey is a specialist in ocean energy roadmaps, action plans and strategies. In 1998 he was awarded a BEng in Mechanical Engineering with 1st class honours from Robert Gordon University and he subsequently attained an MBA degree from Aberdeen Business School in 2006. Following completion of his undergraduate qualification, Henry took the role of Development Engineer with Scottish wave energy developer Wavegen where he remained for 5 years, gaining invaluable industrial experience at the cutting edge of the ocean energy sector. Henry then moved to the University of Edinburgh, where he is currently a Senior Lecturer and leads the Policy and Innovation Group in the Institute for Energy Systems. In this role he contributes to a diverse range of national, European and international ocean energy R&D projects. He leads work on many roadmap and strategy studies and is the coordinator of the EU funded DTOcean project. In addition to his roles at the University of Edinburgh, Henry is the coordinator of the European Energy Research Alliance (EERA) Ocean Energy Joint Programme, serves as Head of Strategy and Internationalisation at Wave Energy Scotland, is responsible for industrial liaison at the SuperGen UK Centre for Marine Energy Research (UKCMER) and has been involved with the IEA Ocean Energy Systems initiative as both UK representative and vice-chair. Henry has authored or co-authored over 30 journal and conference papers along with many of the most notable roadmap and strategy reports in the ocean energy sector.

EXECUTIVE SUMMARY

DR. ANA BRITO E MELO
OES Executive Secretary

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 2016.*

INTRODUCTION

The IEA Technology Collaboration Programme on Ocean Energy Systems is one of the collaborative R&D Programmes established within the IEA, and since its establishment in 2001, the OES participants have been conducting a variety of joint projects. During 2016, the Executive evaluated the achievements of its present 5-year term that will end up in February 2017 and prepared a new Strategic Plan for its 4th 5-year mandate (2017 – 2022).

The End of Term Report and new Strategic Plan were submitted to the IEA and presented by the Chairman in the Renewable Energy Working Party meeting in Beijing, China (17 -18 October 2016).

2016 was marked by the entry of three new members: **India**, **France** and the **European Commission**. On the other hand, Australia, after being inactive for 2 years, withdrew the OES, but with a strong hope to soon re-join and to make efforts to identify the appropriate entity to represent the Government in the OES.

At the end of 2016, OES has 25 members, which provide a broad international base of information, sharing experience and knowledge and further a diversified representation of interests: members are from governmental departments, utilities, universities and research organizations, energy agencies and industry associations. This is one of the benefits of joining OES: participants gain an international perspective on ocean energy issues, opportunities and present challenges.

The OES international co-operation facilitates:

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

This Executive Summary provides a brief summary of the 2016 OES Annual Report. It synthesizes the main achievements in the OES collaborative activities and presents relevant policies and projects by each OES member country. As in previous years, this Annual Report includes a contribution by acknowledged experts from testing centres. Representatives from 5 open sea test centres (EMEC/UK, FORCE/Canada, Oregon/USA, Nagasaki Marine Industry Cluster Promotion Association/Japan and BIMEP/Spain) have been invited to respond to a few questions related with the role of these test centres, difficulties and opportunities.

OES KEY ACHIEVEMENTS IN 2016

The OES held two ExCo Meetings in 2016: The 30th and 31st meetings were convened in Gothenburg, Sweden (9 – 10 May 2016), and Singapore (10 - 11 November 2016).

By late 2016, eleven research projects (Tasks) were established within the OES programme, of which nine are currently operational:

TASK 4 . Assessment of Environmental Effects and Monitoring Efforts for Ocean Wave, Tidal and Current Energy Systems (Annex IV) - providing access to knowledge and information related to research, monitoring, and evaluation of environmental effects of offshore renewable energy.

A State-of-the-Science of environmental impacts of marine renewable energy report was published in 2016. Tethys, the online knowledge management system, continued to expand and to increase user interactions. In addition, 4 environmental webinars, 2 online expert forums and 2 workshops were organised during the year.

TASK 5 . The Exchange and Assessment of Ocean Energy Device Project Information and Experience (Annex V) - promoting the sharing, interchange, evaluation, and compilation of information on OES projects from participating member countries.

A Workshop on Ocean Energy Policies was organized by the U.S. Department of Energy and hosted by the Swedish Energy Agency in Sweden on 12 May 2016.

TASK 6 . Worldwide Web GIS Database for Ocean Energy – interactive web based GIS mapping application with detailed global information related to ocean energy.

Information has been continuously updated on ocean energy facilities, resources, relevant infrastructure, in conjunction with the respective location on a global map.

TASK 7 . Cost of Energy Assessment for Wave, Tidal and OTEC – to deliver the assessment of a credible levelised cost of electricity (LCOE) based on international projects, and the likely future LCOE reduction trajectories of ocean energy projects at a global scale.

The final report of this study was published in 2015, providing an authoritative view on what cost reductions are feasible at a global level, taking into account the experience from other technologies, and further examining opportunities for cost reduction. In 2016, the ExCo agreed to keep this task open and prepare the Terms of Reference to update the LCOE report, in 2017.

TASK 8 . Consenting Processes for Ocean Energy on OES member countries – with inputs from all OES member countries, providing a coherent overview of several aspects of the consenting processes, addressing Marine Spatial Planning policies and site selection for ocean energy development, regulatory issues, environmental impact assessment requirements, consultation and challenges to the consenting process.

A report "Consenting Processes for Ocean Energy: Update on Barriers and Recommendations" was published in 2016 with 10 recommendations.

TASK 9 . International Ocean Energy Technology Roadmap – with the overall objective to develop a roadmap aiming to achieve LCOE targets within the ocean energy sector with a special focus on two key areas: Reliability Improvement and Performance Improvement.

An International Vision for Ocean Energy was prepared in 2016 to be launched in early 2017.

Task 10 . Wave Energy Modelling Verification and Validation – to verify and validate numerical models used in the design and power production evaluation from Wave Energy Converters.

A first workshop was organised and a work plan was agreed among the 18 participants.

Task 11 . Investigation and Evaluation of OTEC Resource - to promote dissemination and demonstration of OTEC by assessing the resource potential and the state-of-the-art of technology.

Two sub-groups were created lead respectively by China and Korea to develop a Task on resource assessment and state-of-the-art of OTEC technology.

The OES has been continuously interacting with the IEA and with other international organizations and networks, including INORE, OECD, IRENA, IEC-TC 114, European Energy Research Alliance (EERA) Ocean Energy Joint Programme, OCEANERA-NET and Ocean Energy Forum.

In 2016, a **Discussion Paper** examining the prospects and potential of the ocean energy sector was prepared, in the scope of the OES contribution to the OECD project on the Future of the Ocean Economy.

The OES was present in 5 relevant international events: the Bali Clean Energy Forum, co-hosted by the IEA and the Indonesian Government, the Asian Wave and Tidal Energy Conference in Singapore, and three conferences in Latin America (Colombia, Chile and Argentina).

OCEAN ENERGY POLICIES IN MEMBER COUNTRIES

Ocean energy is promoted by governments as a renewable source of energy that will help to tackle climate change and contribute to energy security. OES member countries are developing specific strategies and plans for ocean energy and committing national funding for ocean energy research, development and deployment (RD&D).

The year 2016 witnessed relevant governmental initiatives around the world:

- In the **United States**, the Department of Energy (DOE) has been actively involved in the preparation of a National Strategy for Marine and Hydrokinetic energy. Stakeholders were invited to give feedback on it by the end of 2016. One of the goals of the plan is to support research to reduce deployment barriers and to accelerate project permitting processes. In 2016, the total governmental funding for ocean energy amounted to $44.3 million, of which $27.3 million were allocated to new calls for ocean (and river) energy RD&D projects, addressing key technical and market barriers to commercial deployment in USA. In December 2016, up to $40 million was awarded to develop an open-water, grid-connected national wave energy testing facility in Newport, Oregon, by the Northwest National Marine Renewable Energy Center at Oregon State University. The development of comprehensive testing infrastructures is a strategic imperative for the DOE Water Power Program to successfully address sector challenges. Further, the outcomes of the Wave Energy Prize, a public prize challenge also sponsored by the DOE Program, were announced in late 2016: AquaHarmonics, CalWave Power Technologies and Waveswing America were awarded first, second and third place, respectively.

- The Government of **Canada** has been supporting the advancement of a legislative framework for offshore renewable energy which have included broad stakeholder engagements in 2016 and additional stakeholder engagements planned for 2017 conducted by Natural Resources Canada involving provincial and territorial governments, industry associations, environmental organizations and indigenous organizations. At the provincial level, Nova Scotia is getting ready to release *Marine Renewable Energy Regulations*, which will lead to the designation of an area for marine energy development. To date, over $50 million national public funding has been committed to marine energy since 2010; Nova Scotia has directly invested in the FORCE development initiative through a contribution of $11 million, in addition to the support for a number of strategic research projects in marine energy.

- **Mexico** reached, in 2016, the final agreements for the creation of the Mexican Centre for Innovation on Ocean Energy (CEMIE-Ocean). This initiative is seen as a collaborative effort between the government, academia and industry in scientific and applied research for ocean energy and training. It will formally start activities at the beginning of 2017.

- In 2016, a new Action Plan for Energy (2016-2030) was released by the **Chinese** Government with specific goals for marine renewable energies by 2030. Also in December last year, the Government release the 13th Five-Year Plan for Renewable Energy with a target of 50 MW by 2020 for ocean energy. This plan promotes the construction of ocean energy test sites. In 2016, RMB 100 million budget were granted by SFPMRE (Special Funding Plan for Marine Renewable Energy) to support 6 projects. To date, China has committed approximately RMB 1 billion to marine renewable energy RD&D, since 2010.

- The **Republic of Korea** has a national strategy for the development of ocean energy, approved by the Government in 2015. Its key action plan is to stimulate R&D and commercialization of ocean energy technologies. Market incentives for renewables based on the Renewable Energy Certificates (REC) policy have been implemented. In order to accelerate market development, the currently REC value for tidal current of 2.0 is under review, considering to be increased. In addition, the inclusion of wave and ocean thermal energies in REC policy has started to be discussed.

- **New Zealand** has been developing a strategic approach to the Government's research investment in marine resources, known as "Sustainable Seas National Science Challenge". The Challenge aims to support the development of new environmentally sustainable technologies and activities that will add value to the marine economy. Two calls for proposals were launched in 2016 with a partial focus on the Blue Economy.

TABLE 1: POLICY SUPPORT MECHANISMS

	NATIONAL STRATEGY				MARKET INCENTIVES						FINANCING		
	Ocean energy targets	Roadmap for ocean energy	Detailed resource assessment	Marine spatial plan	Feed-in tariff or Premium	ROC	Tradable green certificates	RE portfolio standard	Open sea testing centers	Streamlined licencing regime	Fundamental R&D	Protoype testing	Testing centers
Australia			x	x							x	x	
Belgium			x	x			x		x	x	x	x	
Canada	x	x	x	x	x				x	x	x	x	x
China	x	x	x	x					UD		x	x	x
Denmark		x			x				x	x	x		
European Union		x									x	x	x
France	x		x	UD	x				x	UD		x	x
Germany			x	x						x	x		
India			x								x	x	
Ireland	x	x	x	UD	x				x	UD	x	x	x
Italy	x				x						x	x	x
Japan		x	x						x		x	x	x
Korea	x	x	x				x	x	UD		x	x	
Mexico							x				x		
Netherlands			UD						x				
Monaco				x						x			
Norway				x			x		x		x		
New Zealand			x	x					UD				
Nigeria			UD										
Portugal	x			x					UD	x	x	x	
Singapore									UD		x	x	x
South Africa		UD											
Spain	x		x						x	UD	x	x	x
Sweden			UD	UD			x		x		x	x	
United Kingdom	x		x	x	x	x			x	x	x	x	x
USA			x	x					x	UD	x	x	x

Updated: December 2016
Source: OES

UD: Under development

- **In Singapore**, more than S$140 million public funding has been allocated for research into clean energy. Ocean renewable energy has been identified as one of the prominent alternative energies specifically towards remote coastal and islandic regions.

- 2016 has been another active year for the ocean energy sector in the **United Kingdom**. Policy in relation to tidal lagoons developed significantly during the year with a Government commissioned review of the strategic role of tidal lagoons in the UK. An innovative and unique approach to the development of wave technology has been running since 2014 by the Scottish Government - the funding technology development programme known as Wave Energy Scotland (WES): In 2016, WES committed £12 million in funding and announced 10 awards totalling £3 million for structural materials and manufacturing processes projects. Also, the Welsh Government remains in strong support of the ocean energy sector with several initiatives, in 2016, to support development of the sector.
  FORESEA, one of the biggest EMEC projects started in 2016 – €11 million European programme to support open sea testing for ocean energy. Led by the European Marine Energy Centre (EMEC), the FORESEA project provides funding support to ocean energy technology developers to access Europe's world-leading ocean energy test facilities. The first call for applications was closed in September, with 10 successful ocean energy developers announced.

- In **Ireland**, all relevant agencies and Government departments are coordinating efforts to support the development of an ocean energy industry in the country. Environment, Infrastructure and Job Creation are the tree key work streams of the national Offshore Renewable Energy Development Plan (OREDP) being implemented. 2016 saw two draft environmental guidance documents for the offshore renewable energy industry released for public consultation, aiming to ensure there is clear guidance for developers and ensuring best practices are adopted in order to develop the industry in an environmentally friendly manner. In 2016, seventeen new projects were awarded funding of the Sustainable Energy Authority of Ireland's Prototype Development Fund, including physical tank testing of early stage wave energy concepts.

- In **Spain**, a specific strategy for ocean energy has been defined in one region, the Basque Country: 60 MW for ocean energy by 2030 is the target approved by the Basque Government in 2016 in its Energy Strategy for 2030.

- **Portugal** created an Inter-Ministerial Working Group, called 'Energy at Sea', with the mission of discussing a strategy to develop offshore marine energy in Portugal. The first output of this group was a roadmap for the industrial development of marine renewable energies (waves and offshore wind) approved by the Government and released by the end of the year.

- One call for tenders for commercial tidal arrays has been announced in **France** to be opened by 2017. Also newly awarded funds by the national funding agency, ADEME, for river turbine arrays have been announced in 2016. France opened a consultation for its Marine Spatial Planning (MSP) during the year and dedicated sites for ocean energy projects are now being identified.

- The North Sea Spatial Agenda developed in **The Netherlands** 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 conditions (relatively low tidal heads and speeds).

- In **Norway**, wave energy was mentioned in the White Paper on energy policy published by the Government in 2016.

- Since 2015, a national maritime strategy is in place in **Sweden** with identified areas where actions are needed to promote a sustainable development in the Swedish maritime sector. Ocean energy is one of these areas addressed in the plan. The Swedish Energy Agency is running a national ocean energy programme with a total budget of around €5,7 million for four years. A total of 16 projects have already been approved.

- In November 2016, the **European Commission** published the Ocean Energy Strategic Roadmap developed by the Ocean Energy Forum. The roadmap identifies several priority areas for technological progress. Based on current and planned deployments of wave energy converters and tidal stream devices, the sector is expected to move to the pre-industrial phase by the mid-2020s.

PROGRESS ON OPEN SEA TESTING

2016 saw many positive developments in ocean energy projects worldwide. Elsewhere, notable projects have come into construction, deployment and testing over 2016:

THE UNITED STATES

In the United States significant investments and efforts were made in 2016 toward realizing commercial ocean energy technology. U.S. has a number of initiatives going on related with several testing facilities: The Pacific Marine Energy Center (PMEC), consisting of two operational test sites - the North Energy Test Site (NETS), off the coast of Newport, Oregon, and Lake Washington in Seattle, Washington – have both been operated by the Northwest National Marine Renewable Energy Center, which is a partnership between Oregon State University, the University of Washington, and the University of Alaska Fairbanks. They are now progressing with the development of a full scale, open-ocean, grid-connected wave energy test facility that has been selected for an award that would fund its design, permit and construction. The Southeast National Marine Renewable Energy Center (SNMREC), an Ocean Current Test Facility operated by Florida Atlantic University, is working to advance research in open-ocean current systems. The Hawaii National Marine Renewable Energy Center (HINMREC) is supporting the Navy in the operation of the Navy's Wave Energy Test Site (WETS) operated by the U.S. Naval Facilities Engineering Command, and hosts an Ocean Thermal Energy Conversion (OTEC) Test Site. Several other developments are taking place in testing facilities in North Carolina, New Hampshire and Maine.

Among recent developments is the successful construction and test of one of the world's largest magnetically geared generators for direct-drive applications by ABB. Several other projects are moving ahead:

- Columbia Power Technologies, Inc., (CPwr) has commenced dry testing of the commercial scale PTO at NREL;
- Fred Olsen wave energy converter - the BOLT Lifesaver - has successfully been tested at the Navy's Wave Energy Test Site since its deployment in March 2016;
- Ocean Energy USA is progressing to initiate tests in 2017 at the Navy's Wave Energy Test Site;
- The Azura wave energy device has been testing a half scale device for 19 months since 2015 and will now progress to full scale;
- Columbia Power Technologies, after 10 years of development effort, will be deploying a new improved wave energy device at sea;
- Verdant Power continues prior work on cost-effective O&M procedures;
- Igiugig Village, Alaska, has partnered with Ocean Renewable Power Company (ORPC) to develop the RivGen Power System, a submerged cross-flow river current turbine system;
- Resolute Marine Energy has been working on the development of control systems for Oscillating Wave Surge Converters (OWSC), with plans to deploy a full scale system at Camp Rilea, Oregon.

CANADA

2016 marked a significant event for FORCE when Cape Sharp Tidal, a berth holder at FORCE, installed their first 2 MW turbine and completed the subsea cable connection in early November 2016. This turbine is now generating electricity for Nova Scotia. Another 20 MW of in-stream tidal energy deployments are planned to be deployed in the next two years at the FORCE site: Cape Sharp Tidal Venture (2 MW), Black Rock Tidal Power (5 MW), Minas Tidal Limited Partnership (4 MW), Atlantis Operations Canada (4.5 MW) and DP Marine Energy (4.5 MW).
The 20 MW Annapolis Royal tidal barrage power plant from 1984 continues to operate today. Other projects in Canada have achieved significant milestones during the year:

- Water Wall Turbine deployed 500 kW in-stream tidal turbine at Dent Island, BC, in June 2016;
- Idénergie tested 6 river hydrokinetic turbines in 2016, in British Columbia;
- Mermaid Power Corporation deployed its Neptune wave energy device on Keats Island, in early September 2016;
- New Energy Corp. has been working in Manitoba to supply a 25 kW EnviroGen Power Generation System;
- Mavi Innovations will be deploying a floating tidal turbine at Blind Channel Resort and Marina is scheduled for spring 2017;
- Mermaid Power Corporation has been introducing modifications for a new device, Neptune 4, targeted for deployment in summer 2017;
- Yourbrook Energy Systems launched a pilot project in Haida Gwaii in the Juskatla Narrows of Masset Inlet;
- Big Moon Power successfully completed the test of their Kinetic Keel technology in the upper Bay of Fundy and are now planning their next steps.

MEXICO

A new wave energy device is being developed in Mexico as the result of the collaboration between industry and academia. The device is expected to be deployed close to the facilities of the port El Sauzal, Baja California, and laboratory experiments will be conducted during 2017.

CHINA

In 2016, there was good progress with the development of their three national test sites: the small scale test site in Weihai Shandong province, the tidal energy full scale test site in Zhoushan, Zhejiang Province, and a wave energy full scale test site in Wanshan, Guangdong Province. Several projects in China have shown good progress:

- The platform of the LHD Tidal current energy demonstration was deployed near the Xiushan Island in March 2016. This platform plans to accommodate 7 turbines with installed capacity of 3400 kW, 2 of which have already been installed (#1 turbine: 400 kW, #2 turbine: 600 kW) and connected to the grid;
- The 120 KW turbine, installed by Zhejiang University (ZJU) near the Zhairuoshan Island, has been operating since 2015 and has accumulated over 30 MWh. New turbines are planned to be installed in 2017;
- The hybrid project (wave, wind, bioenergy and solar energy), which includes a 300 kW, wave energy device has been approved by SOA;
- A number of other R&D tidal current and wave energy projects were tested in 2016, with the support of SFPMRE and lead by Chinese Universities. One of these projects, the 100 KW prototype of Sharp Eagle Wanshan deployed in Wanshan Islands since November 2015 has accumulated over 30 MWh till June 2016;
- An OTEC system was installed in 2016 with governmental support.

REPUBLIC OF KOREA

Korea has been conducting an R&D project led by KRISO aiming to develop a 10 MW wave and offshore wind hybrid power generation system for deep ocean, involving 15 universities and research institutes and 10 industrial companies, funded by the Korean Government. Another R&D project supported by the Government was initiated in 2016: the development of an integrated energy storage system and wave energy converters, applicable to breakwaters in remote harbours. The research and development project of a 1 MW arrayed-buoy wave energy converter, using the "Salter's duck" concept, started in December 2016 and is expected to be ended by 2020 with sea trials near Jeju Island.

2016 saw relevant achievements in Korea:

- The construction of the 500 kW Yongsoo OWC Pilot Plant, 1.5 km Offshore Jeju Island was completed in July 2016 and has been operational since then;
- INWave Onshore-Based wave energy plant developed by INGINE was deployed is the sea in close proximity to the shoreline. Since the installation of its first 135 KW pilot plant on Jeju Island, in late 2015, the plant has been in operation, connected to the grid;
- The "30 KW Heaving Semi-spheres with Hinged Arm Wave Energy Converter Platform" project conducted by Hwa Jin Co., was successfully concluded in 2016, with the installation of the prototype near Hupo-hang in the East Sea;
- An Active-controlled Tidal Current Power Generation System (200 kW) was manufactured and is expected be deployed in 2017;
- Since 2012, the development project for the 300 KW Floating Pendulum Wave Energy Converter has been carried out by KRISO with the support from MOF. In 2016, its construction was completed and it is planned to be tested at the open sea test centre of Jeju in 2018;
- 20 KW OTEC and 200KW HOTEC plants are in operation and conducting the performance test at the Sea Water Utilization Plant Research Centre (SUPRC), in Gangwon-do Goseoung-gun. For the commercialization phase, KRISO is in charge of manufacturing a 1 MW OTEC demonstration plant, which is expected to be completed in 2018 and after tests transferred to Tarawa, Kiribati, in 2019.

INDIA

India continues the development of two types of floating wave energy devices, namely the backward bent ducted buoy (BBDB) and a wave powered navigational buoy. This second prototype will be tested offshore Chennai. Design of an OTEC powered desalination plant in Kavaratti, in the Union Territory of Lakshadweep, has commenced and scheduled completion is 30 months. India is also involved in the development of low temperature thermal desalination plants. The marine hydrokinetic turbines for Indian waters have low speeds and medium range torques and NIOT has been developing expertise to deliver products for these particular conditions.

SINGAPORE

2016 was seen as a successful year in Singapore with completion of different projects and a stronger regional commitment towards more innovative and effective means of fully utilising ocean energy sources towards tropical remote regional needs. Among these initiatives is the Renewable Energy Integration Demonstrator-Singapore (REIDS) project aiming to power an island in the south of Singapore only through renewables, including ocean energy. This project, led by the Nanyang Technological University (NTU) and supported by the Singapore Economic Development Board (EDB) and National Environment Agency (NEA), is expected to be completed by December 2017.

NEW ZEALAND

The New Zealand Marine Energy Centre ("NZMEC"), to be located in the Wellington region, is currently on-hold awaiting investment. It will aim to provide ocean based pre-commercial scale testing services for wave and tidal energy device developers.

The initial technology development, called Wave Energy Technology New Zealand or WET-NZ, conducted in New Zealand by Callaghan Innovation (formerly Industrial Research Limited), completed a year's worth of testing in 2016 at the U.S. Navy's Wave Energy Test Site at the Marine Corps Base Hawai'i and it is now preparing for a grid connection.

UK

The year 2016 closed with some remarkable progress for ocean energy in UK:

- Nova Innovation began exporting power to the grid with its first two turbines off the coast of Shetland Isles, with plans to further develop the Shetland array in 2017;
- The MeyGen array, operated by Atlantis Resources in Scotland's Pentland Firth, made significant construction progress in 2016 for phase 1A of the project (4 turbines, 6 MW);
- Carnegie Clean Energy have entered an agreement to install a 15 MW array of the CETO 6 wave energy converter at the Wave Hub site;
- Scotrenewables has begun testing a floating tidal turbine at EMEC and is applying for consent to deploy a 10 MW array in Orkney.

Several developers - including CorPower, Laminaria, Tocardo Tidal Power and Nautricity - are progressing with demonstration projects expected to be tested at EMEC in the course of 2017. Tidal Lagoon Power Ltd. have plans to construct a 320 MW capacity tidal lagoon scheme in Swansea Bay, Wales; the Consent was awarded in 2015 and the construction is expected for 2018.

IRELAND

2016 has seen good progress with some flagship projects developed by Irish companies:

- SeaPower Ltd. developing a wave attenuator called the SeaPower Platform tested a device at the quarter scaled Galway Bay test site in November 2016;
- GKinetic Ltd. has been developing a submerged tidal energy device which was tested at 1:10 scale in Limerick Docks and is planned to be re-deploy in 2017;
- ESB's WestWave 5 MW wave energy project to be deployed on the west coast of Ireland, near Killard is progressing with field activities to secure the required permits.

FRANCE

Two test sites in France are fully operational: SEM-REV for testing wave and offshore wind projects and SEENEOH, an original estuarine tidal test site for full scale river and intermediate scale ocean tidal devices.

Operational projects in France and planned deployments include:

- The tidal range barrage of 240 MW of the Rance river, running since 1966;
- Sabella, the first and currently only marine tidal turbine to have provided electricity to the French electricity grid, has completed a series of tests in Ouessant and qualified for the ICE project (Interreg trans-English Channel Brittany/Cornwall) for the use of the D10 tidal turbine for 2 to 3 years in the Fromveur tidal race (Brittany);
- Hydroquest River 1.40 is the only grid-connected fluvial hydrokinetic turbine in operation in France. Projects are currently underway also in Africa, Asia and South America;
- In Paimpol-Bréhat (Brittany) EDF and Openhydro - a DCNS Energies Company, have deployed and connected in 2016 two OpenHydro 16 m diameter tidal turbines and a subsea conversion system developed by GEEPC, thus completing the architecture of the demonstration farm.
- Guinard Energies is progressing to deploy, in 2017, the 250 kW MegaWattBlue tidal demonstration turbine in the Ria d'Etel (South Brittany);

- The Normandie Hydro tidal turbine pilot farm project, located in the Raz Blanchard tidal race, is progressing through the construction and installation stage. Planned for a 20-year period of operation, the 14 MW farm of 7 OpenHydro tidal turbines is coordinated by DCNS in cooperation with the French utility EDF;
- HYDROQUEST and CMN, together with the University of Caen Normandy, were awarded funding, in February 2016, to install a Hydroquest demonstrator turbine of 1 MW on the Paimpol-Bréhat EDF test site in autumn 2017;
- France is also heavily investing in OTEC: a 10.6 MW OTEC floating plant is being developped for the Martinique caribbean island.

MONACO

In Monaco, ocean energy activities are related with the demonstration of sea water heat pumps to generate energy. The number of sea water heat pumps is expected to increase in the near future.

SPAIN

The Mutriku wave power plant completed its first five years of continuous operation reaching, by the end of 2016, a record of cumulative energy produced from waves with more than 1.3 GWh injected into the power grid. Also in the Basque Country, the Biscay Marine Energy Platform (BiMEP) open sea test centre promoted by EVE and IDAE, has been in operation since its inauguration in July 2015.

In 2016 several Spanish projects achieved good milestones:

- The so called MARMOK-A-5 device, developed by OCEANTEC, was deployed in October at BiMEP and grid connected, delivering the first kWh in December. This is the first floating wave energy device connected to the grid in Spain;
- An offshore platform was installed at PLOCAN on the Canary Islands, which together with the electrical infrastructure expected in early 2017 will allow PLOCAN to be fully operational in 2017;
- The wave energy device prototype developed by Wedge has been tested at PLOCAN site;
- Rotary Wave developed a 1:4 scale device to demonstrate its Butterfly technology in the Mediterranean Sea.

PORTUGAL

In 2016, there were two active developers in Portugal: AW-Energy from Finland and Bombora Wave Power from Australia. Bombora has been taking the first steps, preparing the documentation to apply for the licence of a first prototype in Portugal; AW-Energy has been working with Portuguese authorities to license the first-of-a-kind commercial scale device expected to be built and deployed during the spring/summer of 2017, with funding from the InnovFin Energy Demo Projects (EDP) scheme, a joint initiative by the EIB Group and the European Commission. Simultaneously, AW-Energy has also started to plan their first wave energy park in Peniche - the project called “Ondas de Peniche” winner of the NER 300. Pico OWC plant in Azores produced over 39 MWh in 2016.

ITALY

The Italian company Enel Green Power with DCNS from France have been selected by the Chilean Government’s economic development organization CORFO (*Corporación de Fomento de la Producción*) to set up a centre of marine energy R&D excellence in Chile, named Marine Energy Research and Innovation Centre (MERIC).

In Italy, a number of successful projects were active in 2016:

- The first full scale prototype (100 kW) of GEM, “the Ocean’s Kite” turbine built by a consortium of Venetian companies, has been deployed in the Venice Lagoon. The next step will be the development and deployment of a 200 kW in the Strait of Messina;
- A new prototype of the “Kobold Turbine” was built (120-150 kW) and will be placed on the Lomboc Island (east of Bali);
- Enel Green Power has bought the H24 wave energy device from the Italian company 40South Energy and will support the development and commercialisation of the technology;
- Enel Green Power is evaluating an onshore OWC system, a caisson breakwater plant, called REWEC (Resonant Wave Energy Converter) built in Civitavecchia Port;
- The wave energy device called ISWEC has been tested since 2015 on Pantelleria Island;
- The Italian manufacturing company Umbra initiated collaboration with the French start-up EEL Energy, which has been developing an innovative tidal energy device with a flexible membrane actuated by tidal currents; first test campaigns are scheduled for 2017.

BELGIUM

The Flemish wave energy developer Laminaria is planning a deployment at the EMEC test site in Orkney, Scotland in 2017 (LAMWEC project).

DENMARK

The DanWEC wave energy test site was very active in 2016 with two Danish companies Wavepiston and Resen Waves and the German wave energy system NEMOS. Another two devices - Weptos and CrestWing - are making progress to test their devices in 2017 in Denmark.

THE NETHERLANDS

REDstack, a salinity plant in The Netherlands, was rewarded in 2016 as one of the three 'National Icons'. Also, during the year several activities with tidal current projects have been progressing. The 1.25 MW tidal power plant in the Eastern Scheldt, installed by the end of 2015, performed very well during the year.

In the OTEC 2016 symposium in Amsterdam, organised by the Dutch company BlueRise, a Memorandum of Understanding (MoU) was signed between the Dutch Marine Energy Centre (DMEC), the Dutch Energy from Water Association (EWA) and the Ocean Energy Association of Japan.

GERMANY

In Germany there is no ocean energy deployment or testing activity in the sea, however around 15 R&D institutes and universities and a number of companies are active in ocean energy:

- SCHOTTEL HYDRO is developing a prototype of the semi-submersible tidal power platform "TRITON", scheduled to be deployed at the FORCE tidal research centre at the Bay of Fundy, Canada;
- ANDRITZ HYDRO delivered three turbines to MeyGen project;
- Bosch Rexroth has been developing electro-active polymers for power generation and published a final report in 2016;
- The NEMOS GmbH has been testing a 1:5 scale wave energy device at the Nissum Bredning Test Station in Denmark;
- SINN Power GmbH has been tested their first wave power module at the Port of Heraklion, Greece.

NORWAY

In Norway, two prototypes were deployed during 2016: the 250 kW Deep River pilot project and the Tide Tec scaled turbine prototype by Tidetec AS. A number of Norwegian companies are planning deployments to take place during 2017.

Runde Environmental Centre (REC), located on Runde Island on the Norwegian west coast, was active in 2016 with the testing of the Swedish developer Waves4power. This project is now being upgraded to be re-deployed before the end of 2017.

SWEDEN

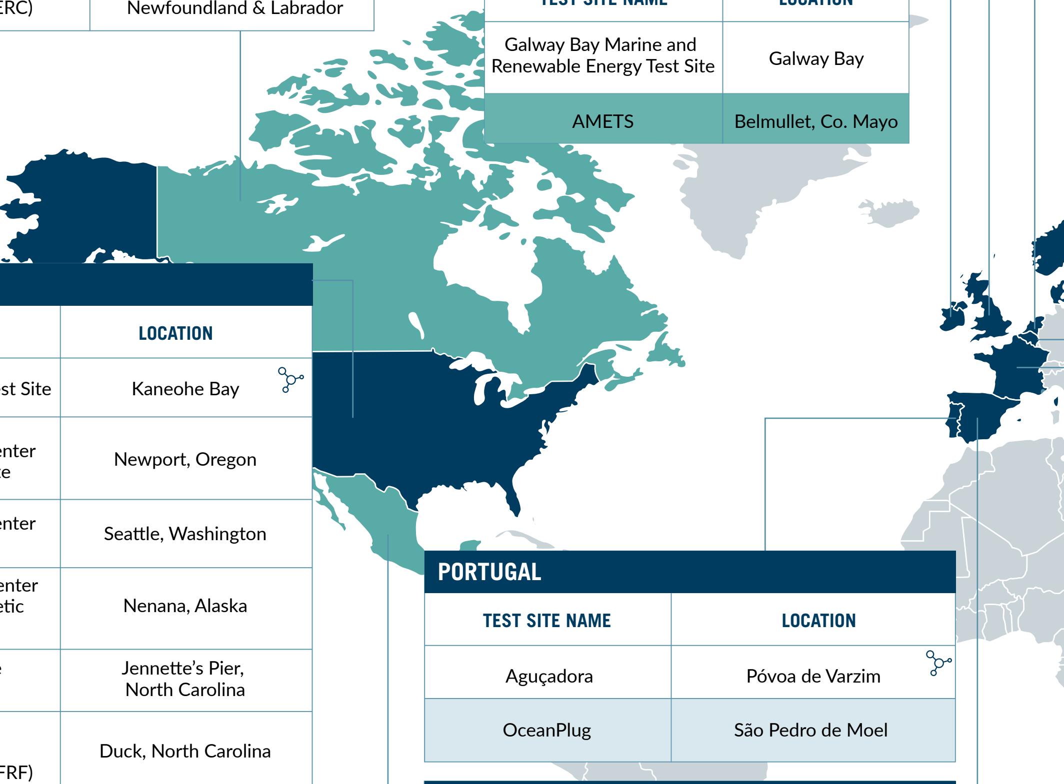
The Lysekil wave energy research test site at the west coast of Sweden has been grid connected since November 2015; at the Lysekil site, preparations have been made during 2016 for next year´s grid connection of three wave energy converters.

Two other projects deployed in Sweden have been operational: the Söderfors marine current project and the Sotenäs project. At Söderfors site, the turbine blades were changed in 2016 and the vertical marine current converter was grid connected. The Sotenäs Project was initiated in November 2011 and 36 wave energy converters (corresponding to 3 MW) have been deployed along with the subsea generator switchgear. The wave power plant was initially grid connected in January 2016. This project is funded by the Swedish Energy Agency, the power company Fortum and by Seabased Industry AB.

Waves4Power is a Swedish company demonstrating a full scale wave power device at sea, in Runde, in Norway. A few other deployments from Swedish companies are planned to take place outside Sweden: Minesto developing Deep Green for low-velocity tidal and ocean currents; CorPower Ocean at EMEC; Seabased signed a contract for a wave energy park in Ghana, which is under installation.

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 Alfond W2 Ocean Engineering Lab	Orono, Maine
UMaine Offshore Intermediate Scale Test Site	Castine, Maine
UMaine Deepwater Offshore Renewable Energy Test Site	Monhegan Island, Maine
Southeast National Renewable Energy Center	Boca Raton, Florida
Pacific Marine Energy Center South Energy Test Site	Newport, Oregon
California Wave Energy Test Center (CalWave)	Vandenburg Air Force Base, California

PORTUGAL

TEST SITE NAME	LOCATION
Aguçadora	Póvoa de Varzim
OceanPlug	São Pedro de Moel

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 | Planned | Grid connected

SWEDEN

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

DENMARK

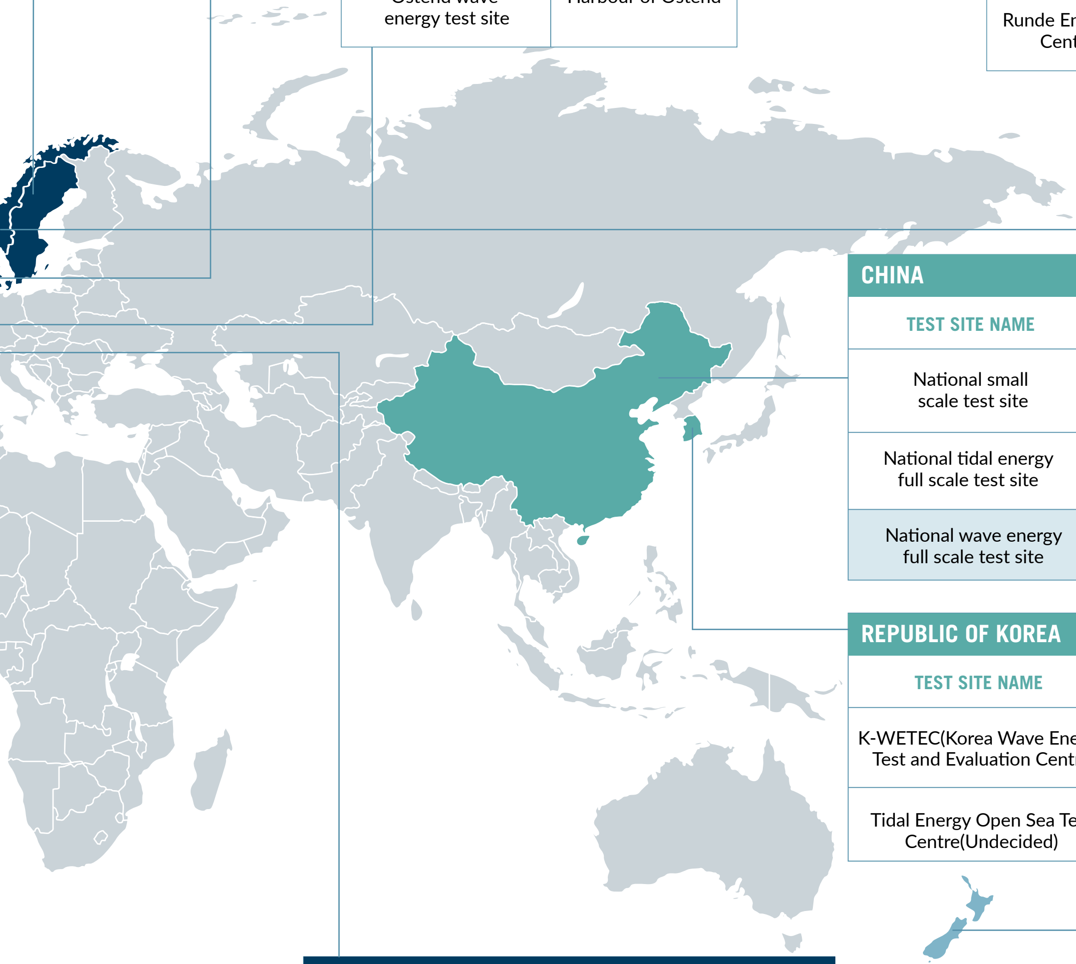
TEST SITE NAME	LOCATION
DanWEC	Hanstholm
DanWEC NB	Nissum Bredning

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
National tidal energy full scale test site	Zhoushan, Zhejiang Province
National 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)	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

NEW ZEALAND

TEST SITE NAME	LOCATION
NZ Marine Energy Centre	Cook Strait

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 1,000 m;
- **Salinity Gradients**, derived from salinity differences between fresh and ocean water at river mouths.

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

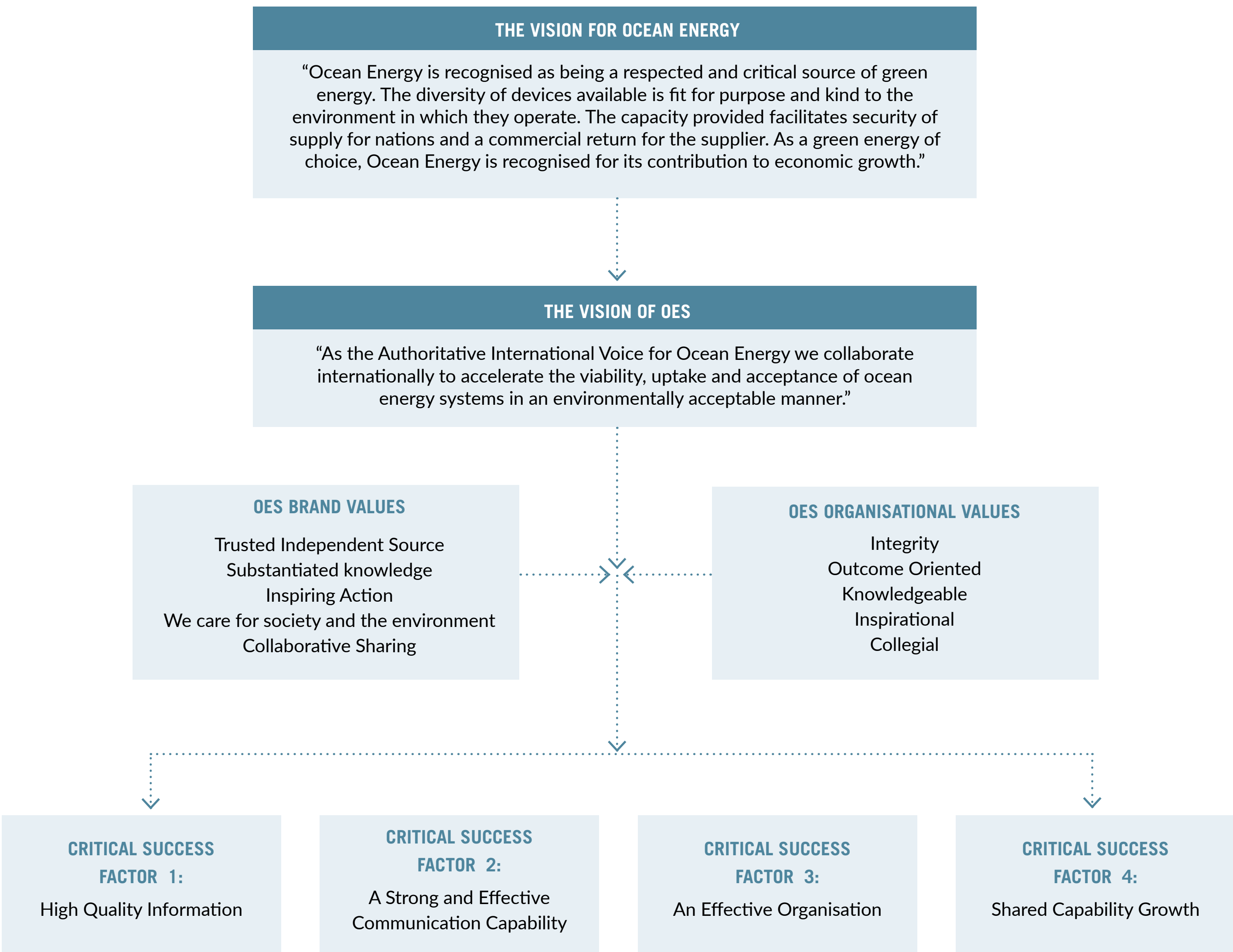
Knowledgeable . All information is based on fact and we strive to ensure that we always have the most relevant and up-to-date researched facts available

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 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. As of December 2016, 25 countries are members of the OES: Portugal, Denmark, United Kingdom, Japan, Ireland, Canada, the United States of America, Belgium, Germany, Norway, Mexico, Spain, Italy, New Zealand, Sweden, Australia, Republic of Korea, South Africa, China, Nigeria, Monaco, Singapore, The Netherlands, India, France and the European Commission ordered by sequence of joining the Agreement.
In 2016 Australia withdraw the OES after being inactive for 2 years. Efforts are pursuing for Australia to re-join OES.

In 2016 India, France and The European Commission joined the OES.

Communication continues with the governments of the following countries: Argentina, Brazil, Chile, Colombia, Finland, Philippines, 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.

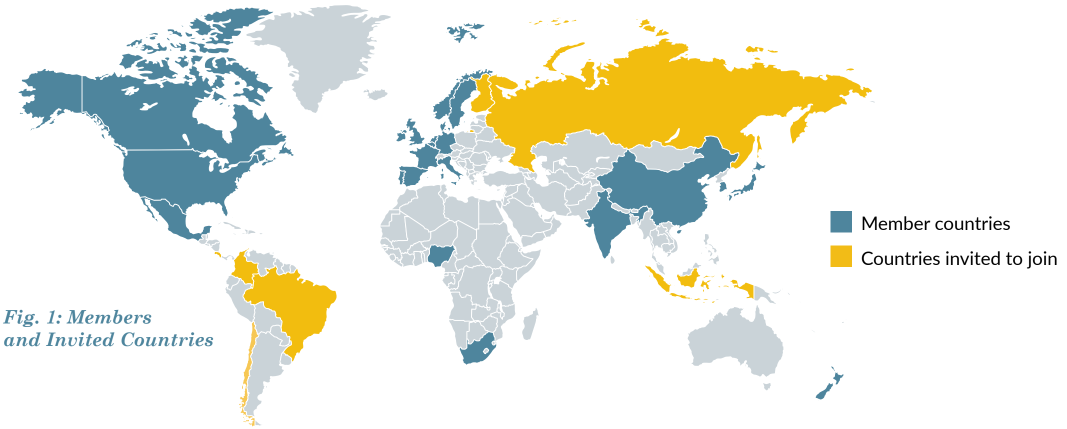


Fig. 1: Members and Invited Countries

Participation in OES builds connections between national governments and industries, creates networks of experts and expands national research capacities

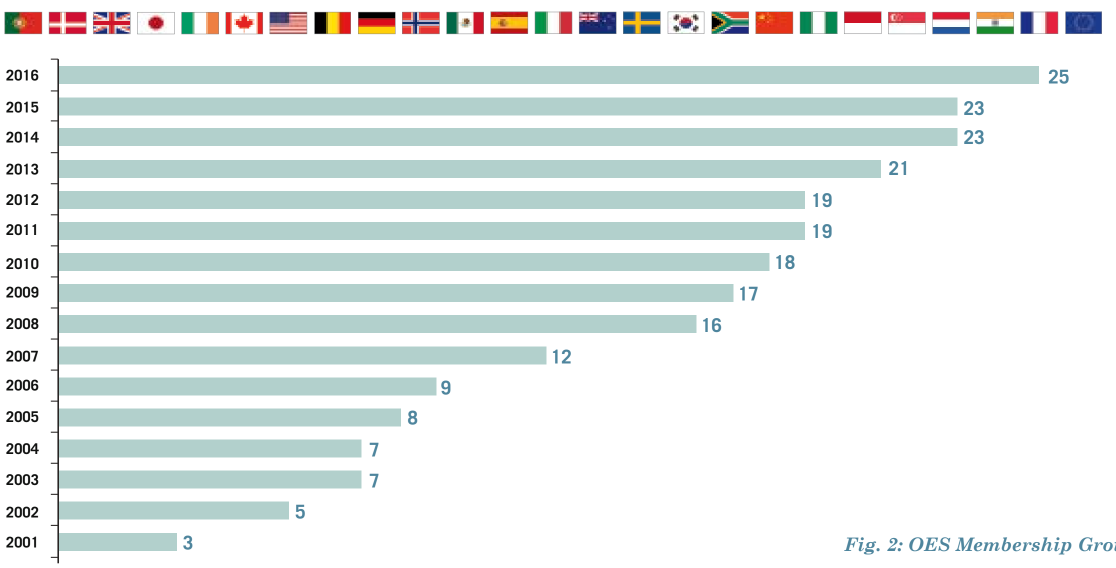


Fig. 2: OES Membership Growth

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. 3). The ExCo considers this diversity to be a key strength of the organization and will strive to maintain this balance of representation.

TABLE 2: CONTRACTING PARTIES
(End December 2016)

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

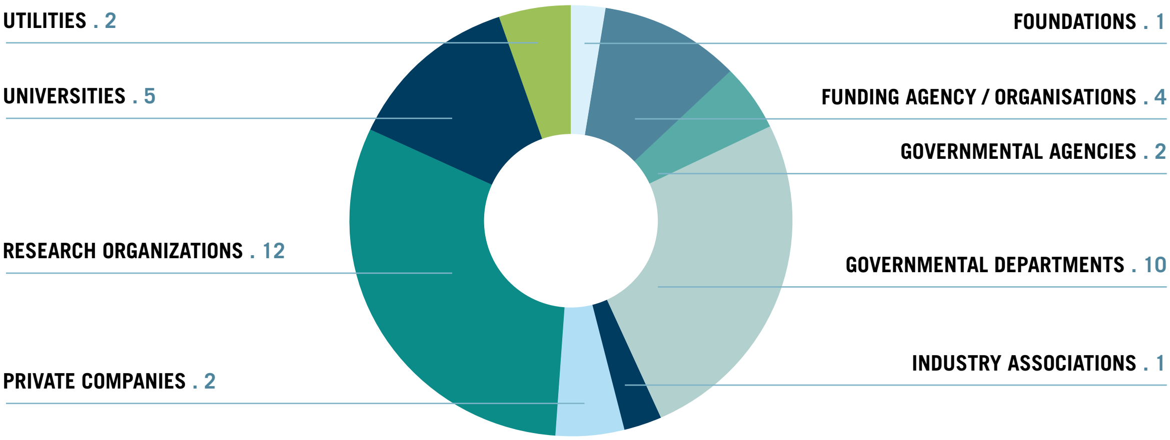


Fig. 3: Diversified representation of interests in the ExCo

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 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 30th and 31st meetings were convened in Gothenburg, Sweden (9 – 10 May 2016), and Singapore (10 - 11 November 2016). A list of the members of the ExCo during 2016 is shown in Appendix 2.

30th ExCo meeting in Sweden (9 - 10 May 2016)

In the November meeting a new Cabinet was elected: The UK alternate, Henry Jeffrey will replace José Luis Villate as Chairman for the period 2017 – 2018. Alison La Bonte (delegate from USA) and José Luis Villate (Spanish alternate) will stand as Vice-Chairs for 2017.

31st ExCo Meeting in Singapore (10 - 11 November 2016)

02.
WORK PROGRAMME

ONGOING TASKS

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. The collaborative research work carried out by the OES are structured into specific projects/tasks, managed by an Operating Agent (OA) and using two distinct approaches:

- **Large projects/tasks -** conducted by a group of countries interested in the topic to which only participants in the project contribute. Whenever three or more contracting parties support a proposal and sufficient funding is raised, a new research project can be established. One of the proposing parties will usually become the Operating Agent, accountable for delivery of the project and management of its dedicated budget. Participation by ExCo members in is voluntary and usually by cost-sharing, task-sharing or both – **"Bottom-Up" approach**.
- **Small projects/tasks -** of interest to all members, usually financed by the Common Fund, so all members are effectively contributing equally to these deliverables. Usually an interested volunteer member prepares the Terms of Reference of any proposed Task. The delegates are invited to bid to participate in this work; applications are evaluated and selected by a sub-committee of 3-4 voluntary ExCo members. The work is then undertaken by a group of members - both through cost- and task-sharing - and may include participation of external experts – **"Top-Down" approach**.

LIST OF TASKS

TASK 1 . Annex I Review, Exchange and Dissemination of Information on Ocean Energy Systems

Duration: From 2001 (continuous)
OA: WavEC (PORTUGAL)
Participants: All member countries (Compulsory membership)

TASK 4 . Annex IV Assessment of Environmental Effects and Monitoring Efforts for Ocean Wave, Tidal and Current Energy Systems

Duration: Phase I: 2010 – 2013; Phase II: 2013 – 2016; Phase III: 2016 – 2019
OA: US Department of Energy (DOE)
Partners: Bureau of Ocean Energy Management (US) and National Oceanic and Atmospheric Administration (US)
Consultants: Pacific Northwest National Laboratory (US), assisted by Aquatera Ltd (UK)
Participants: Canada, China, Ireland, Japan, New Zealand, Norway, Portugal, South Africa, Spain, Sweden, United Kingdom and United States of America

TASK 5 . Annex V Assessment of Environmental Effects and Monitoring Efforts for Ocean Wave, Tidal and Current Energy Systems

Duration: From 2012 (continuous)

OA: Phase I: National Renewable Energy Laboratory on behalf of DOE (USA) (2012 -2016); Phase II: OES Cabinet (2017 --...)

Participants: All member countries

TASK 6 . Worldwide Web GIS Database for Ocean Energy

Duration: From 2013 (continuous)

OA: Fraunhofer Institute IWES (GERMANY)

Participants: All member countries

TASK 7 . Cost of Energy Assessment for Wave, Tidal, and OTEC at an International Level

Duration: 2014 – 2015

OA: The University of Edinburgh (UK)

Partners: WavEC (PORTUGAL), Julia F. Chozas (DENMARK), Re Vision Consulting (USA);
Advisors: RAMBOLL Group A/S (DENMARK), FOT-K Consortium (NIGERIA)

Participants: All member countries

TASK 8 . Consenting Processes for Ocean Energy on OES Member Countries

Duration: 2014 – 2017

OA: WavEC (PORTUGAL)

Consultant: MAREI (Ireland)

Participants: All member countries

TASK 9 . International Ocean Energy Technology Roadmap

Duration: 2015 – 2017

OA: The University of Edinburgh (UK)

Partners: Nanyang Technological University (SINGAPORE), Cardinal Engineering (USA),
Power Projects Limited (NEW ZEALAND)

Participants: All member countries

TASK 10 . Wave Energy Modelling Verification and Validation

Duration: Initiated in 2016 (expected to run during 3 years)

OA: Kim Nielsen (DENMARK)

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

TASK 11 . Investigation and Evaluation of OTEC Resource

Duration: Initiated in 2016 (expected to run during 3 years)

OA: Yasuyuki Ikegami (JAPAN)

Working group leaders: Dengwen Xia (CHINA) and Keyyong Hong (REPUBLIC OF KOREA)

Participants: China, Republic of Korea, Japan, Singapore, India, France and The Netherlands

Details of the ongoing Tasks are available in Chapter 3. The completed projects - Task 2 “Development of Recommended Practices for Testing and Evaluating Ocean Energy Systems” and Task 3 “Integration of Ocean Energy Plants into Distribution and Transmission Electrical Grids” - are summarised in Appendix 4.

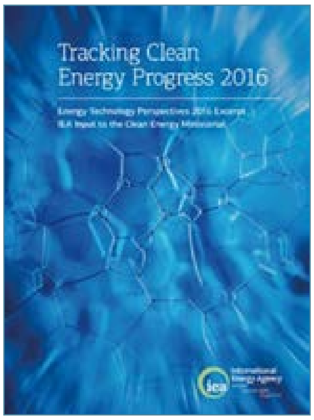
INTERNATIONAL CO-OPERATION

COLLABORATION WITH THE IEA

In 2016 OES collaborated with the **Bali Clean Energy Forum** co-hosted by IEA and Indonesian Minister of Energy and Mineral Resources. It was a two-day event showcases opportunities to accelerate clean energy deployment and enhance energy efficiency around the globe. Organised on the 11th February, it was attended by more than 1000 leaders from government, industry, research and development organizations. Under the theme "Bridging the Gap and Promoting Global Partnership", the Bali Forum aimed to explore how international partnerships can help countries in all stages of development share knowledge, technology and best practices to scale up clean energy deployment.

The Chairman of the OES moderated a session on ocean energy with 6 speakers addressing the following topics: Ocean Energy in Indonesia, Ocean Energy for Island Electrification, Ocean Current Technology and Barrage Utilization of Hydro Power in Indonesia, the South East Asian Marine Energy Centre and tidal energy development, lessons learnt from French experience and Indonesian perspectives.

OES usually interacts with the IEA through contributions to various IEA reports, the IEA OPEN Bulletin and trough participation in IEA meetings.



In 2016 OES participated in the following meetings:

- IEA Workshop "Maximising the impact of IEA's Technology Collaboration Programmes through enhanced cooperation in the Energy Technology Network", Paris, 18 February 2016.
- Sixty-Ninth Meeting of the Working Party on Renewable Energy Technologies, Paris, 15 - 16 March 2016.
- Seventeenth Meeting of the Working Party on Renewable Energy Technologies, Beijing, China, 17-18 October 2016.

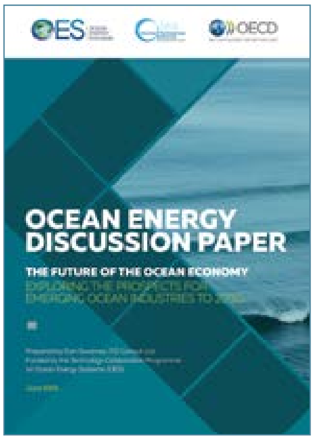
In 2016 the OES reviewed the 'Tracking Clean Energy Progress´' (TCEP 2016). This report highlights the development and deployment of key clean energy technologies year on year. *TCEP* 2016 – prepared for the Clean Energy Ministerial meeting where 23 member countries collaborate on solutions to advance clean energy globally – is an integral part of the specific recommendations to governments on how to scale up deployment of these key technologies to ensure a secure, clean and competitive energy future.

COLLABORATION WITH IEC-TC 114

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

COLLABORATION WITH THE OECD

The OES collaborated with the OECD project "The Future of the Ocean Economy: Exploring the prospects for emerging ocean industries to 2030". The Report was formally launched in 2016 at a 2-day event in Seoul, attended by an international audience of ca. 50 people.
OES contributed with a Discussion Paper, prepared by Eoin Sweeney, on the status of ocean energy which was published in 2016 at the OES website.



OBJECTIVE AND MAIN FINDINGS OF THE OECD REPORT

This project explored the growth prospects for the ocean economy, and its capacity for employment creation and innovation. Particular attention is devoted to the emerging ocean-based industries in light of their particularly high potential for growth, innovation and contribution to addressing global challenges such as energy security, environment, climate change and food security. Hence the present report examines the risks and uncertainties surrounding the future development of ocean industries, the innovations required in science and technology to support their progress, the environmental impacts of the industries, their potential contribution to green growth as well as their negative externalities, and some of the implications for planning and regulation. Finally, and looking across the future ocean economy as a whole, it explores possible avenues for action that could boost its long-term development prospects while managing the use of the ocean itself in responsible, sustainable ways.
The Report states that "the ocean will play a key role in the transition to a more sustainable global energy system. While current global offshore wind installed capacity is in excess of 7 gigawatts (GW), projections suggest there may be potential for 40-60 GW by 2020 and growth of a further order of magnitude by 2050. And while ocean power (wave, tidal, thermal conversion, salinity gradient technology) is not yet mature or operating at commercial scale, its longer term potential is considerable. Both offshore wind and ocean-based energy are expected to gain considerably from future investment in the wake of the Paris COP21 agreement."

More information about the OECD study:
http://www.oecd.org/futures/oceaneconomy.html

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 BECS (Blue Energy Collaborative Scholarship), 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 EUROPEAN INITIATIVES

EERA OCEAN ENERGY JOINT PROGRAMME AND OCEANERA-NET

In 2016, OES organised a join workshop on "Stage Gate Metrics for Ocean Energy Technology Development" with two European initiates, the EERA Ocean Energy Joint Programme and the OCEANERA-NET. The workshop was attended by key stakeholders within the ocean energy industry and was held in Edinburgh on September 16th 2016. The outputs of this workshop are intended to provide a step-forward in the common understanding and approach to success measurement in ocean energy technology and to progress the baseline for future discussions. The workshop also forms a valuable input to the on-going 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. Follow-up workshops will be required to help the ocean energy sectors maintain a common approach as well as provide a forum for individual funders and technology development programme managers to share their experience of specific metrics and success thresholds appropriate to their technologies and markets.

European Energy Research Alliance (EERA) Ocean Energy Joint Programme: The EERA Ocean energy programme aims to contribute to strategic leadership of the underpinning research, joint prioritization of research tasks and infrastructure, alignment of European and national research efforts, coordination with industry and sharing of knowledge and research infrastructure.

Ocean Energy European Research Area Network (OCEANERA-NET): OCEANERA-NET 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 R&D. It is funded by the European Union bringing together 15 European research funding organisations from 8 EU countries.

OCEAN ENERGY FORUM

The Ocean Energy Forum was launched by the European Commission in 2014 which brings together stakeholders to develop a shared understanding of the problems and to develop solutions. The Ocean Energy Forum was formed of 3 work streams for Environment & Consenting, Finance and Technology. These three work streams allowed consensus building to take place at a topic-specific level thus enabling pragmatic solutions to issues to be developed. The OES was part of the Steering Group on Environment & Consenting.

More information at:
https://webgate.ec.europa.eu/maritimeforum

Ocean Energy Forum
The main output is the Strategic Roadmap, published in November 2016, proposing 6 actions to facilitate the emergence of a market for ocean energy in Europe:
- To create an EU-wide phase-gate approach for technology development
- Identify the most suitable sites for early deployments and support pre-commercial farms there
- Create a packaged approach for financing farms
- Create an EU insurance fund to underwrite project risks
- Increase collaboration to reduce costs and plan deployments
- Create an integrated consenting programme

MARIBE ADVISORY SESSIONS

MARIBE is 18-month project that was funded by the European Commission aiming to unlock the potential of multi-use of space in the offshore economy. Having explored the opportunities that exist for cooperation between different Blue Growth and Blue Economy sectors, the consortium worked with companies from these marine sectors to develop 9 multi-use of space or multi-use platform projects. The consortium's expertise was utilised to assist companies with their business and financial models. OES was invited to attend the advisory session events.

More information at: https://maribe.eu

MARIBE objectives:

- Identify opportunities for Blue Growth sectors to cooperate with other sectors via multi-use of space or in multi-use platforms and assist in the development of the most promising project combinations.
- Provide information on the socio-economic context and the key technical and non-technical challenges facing these projects based in part on lifecycle learning.
- Use the consortium's diverse network to introduce project stakeholders to key advisors and potential investors.

03.

MAIN ACHIEVEMENTS IN 2016

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 were 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://report2016.ocean-energy-systems.org/.
- A **Bulletin** issued each semester, after each ExCo meeting presents most up to date information exchanged by the delegates.

PRESENCE IN RELEVANT EVENTS

OES was present in three major events on ocean energy, in South America: Chile, Colombia and Argentina.

Universidad Austral, in Valdivia, Chile, was the home of the second workshop on Wave and Tidal Energy (http://www.waveandtidal.cl/), from 16 to 18 November. The event, that gathered scientists, industry and governmental representatives, gave special attention to R&D breakthroughs that can address risk assessment issues for Marine Renewable Energy projects. OES was present, through the participation of the French Delegate, Yann-Hervé De Roeck.

Also in November, 23 and 24, in Buenos Aires, Argentina, took place the second Siemar (http://www.siemar.com.ar/), International Seminar on Ocean Energy. OES was present,

SIEMAR, Buenos Aires, Argentina, November 2016

Cintecmar Colombia, November 2016

with its Vice-Chair and UK Delegate, Henry Jeffrey. It was an opportunity to gather international experts, to exchange knowledge and experience related to ocean energy.

In October, the OES was also present in the Cintecmar Colombia, the 1st International Congress of new Technologies for Sea and River, this time with the participation of the Executive Secretary of the OES, Ana Brito Melo. The event addressed the scope and challenges of ocean energy development in the country (http://www.cintecmar.com/index.php/en/).

The three events were of major importance for the promotion of the OES activities and an opportunity to interact with governmental representatives that attended the meetings.

Dissemination of OES activities has been an ongoing process, through the presence of OES representatives several events related to ocean energy. The table below lists the main events in 2016, in which the OES was represented.

TABLE 3:
OES PARTICIPATION IN INTERNATIONAL EVENTS DURING 2016

DATE	LOCAL	EVENT
Feb 2016	Edinburgh - UK	ICOE 2016 - International Conference on Ocean Energy
Feb 2016	Edinburgh - UK	Ocean Energy Forum
Feb 2016	Bali - INDONESIA	Bali Clean Energy Forum (co-hosted by the IEA) *OES organized a parallel session on Ocean Energy*
April 2016	Washington DC - USA	International Marine Renewable Energy Conference (IMREC)
June 2016	Paris - FRANCE	Ocean Energy Forum
June 2016	Brussels - BELGIUM	MARIBE advisory sessions *EU-funded project that aims to unlock the potential of multi-use of space in the offshore economy*
Sep 2016	Barranquilla - COLOMBIA	1st International Congress of New Technology for Sea and River
Oct 2016	Delft - THE NETHERLANDS	4th International OTEC Symposium
Oct 2016	SINGAPORE	AWTEC- Asia Wave and Tidal Energy Conference *Paper: Ocean Energy Systems: An International Technology Collaboration Programme, José Luis Villate and Ana Brito-Melo*
Nov 2016	Valdivia - CHILE	WTE'16 - Second Workshop on Wave and Tidal Energy
Nov 2016	Buenos Aires - ARGENTINA	SIEMAR – International Seminar on Marine Energies *Paper: 15 Years of Successful International Collaboration on Ocean Energy; José Luis Villate, Henry Jeffrey and Ana Brito-Melo*
Nov 2016	Brussels - BELGIUM	Ocean Energy Forum – Final Event

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. The next conference in 2018 will be in France. OES secured a host for a new edition in 2018: West Normandy Marine Energy

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

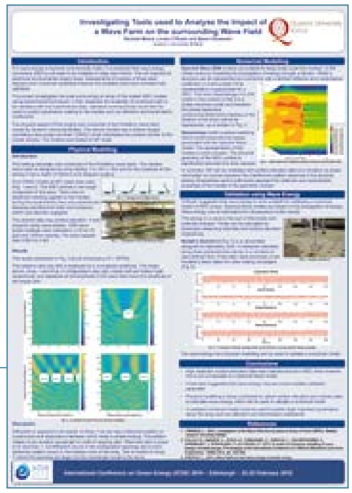
In particular, the OES hosts past ICOE conference material on a dedicated website managed by OES (www.icoe-conference.com), providing the historical archive of all papers from previous ICOE conferences.

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.

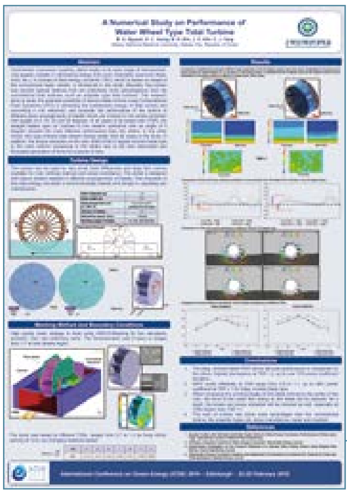
At ICOE 2016, the OES sponsored a €3,000 prize fund to students selected by an international jury for the best posters presented.

ICOE 2016 POSTER AWARDS WINNERS

First prize (€ 1,500):
Anthony Gray (IDCORE)
Study: Identifying Key O&M Strategy Considerations for a Wave Energy Array - A Case Study on Pelamis
Authors: Anthony Gray and Lars Johanning



Second prize (€ 1,000):
Rachael Moore
(Queen’s University Belfast)
Study: Investigating Tools Used to Analyse the Impact of a Wave Farm on the Surrounding Wave Field
Authors: Rachael Moore, Louise O’Boyle and Bjoern Elsaesser



Third prize (€ 500):
H. C. Jeong (Mokpo National Maritime University)
Study: A Numerical Study on the Performance of a Water Wheel Type Tidal Turbine
Authors: M. H. Nguyen, H. C. Jeong, B. G. Kim, J. H. Kim, C. J. Yang

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

In 2016: Jocelyn Brown-Saracino US Department of Energy (DOE)
In 2017: 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, New Zealand, Norway, Portugal, South Africa, Spain, Sweden, United Kingdom and United States of America

FURTHER INFORMATION

http://tethys.pnnl.gov/

OBJECTIVES

Task 4 on Assessment of Environment Effects and Monitoring Efforts 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 development.

The third phase of Annex IV was approved by the OES ExCo in May, 2016. It will build on the work completed during the first phase, by continuing to collect, analyze, and disseminate information, to enhance the development of the marine renewable energy industry by providing access to knowledge and information related to research, monitoring, and evaluation of environmental effects of offshore renewable energy. Supported by the online knowledge management system *Tethys*, developed by Pacific Northwest National Laboratory, a commons is being created for Annex IV that facilitates the broadcast and archiving of webinars, expert forums, and workshops focused on important scientific issues that are critical to the siting and permitting (consenting) of marine energy 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 marine energy devices.

MAJOR ACHIEVEMENTS

During 2016, Phases 2 and 3 of Annex IV highlights include:

- Participation by member nation analysts;
- Collection and update of metadata forms;
- Broad dissemination of information;
- Convening and reporting on targeted workshops;
- Holding webinars; and
- Release of the 2016 State of the Science report.

Progress towards each achievement is described in the following sections.

MEMBER NATION ANALYSTS

Annex IV is characterized by the close involvement of an analyst from each of the 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 marine energy 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 products, such as *Tethys* content and functionality;
- Providing review of the State of the Science report;
- Acting as an ambassador for Annex IV in their respective country;
- Translating the State of the Science Report Executive Summary from English into the official language of their respective country.

COLLECTION AND UPDATE OF METADATA

Information is collected for ongoing marine energy sites and research projects in the form of metadata that describe the project or study, the methods and outcomes of environmental monitoring, and provide contact information for the owners or authors of the reports. 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. This information is subsequently stored and can be accessed from *Tethys*. In addition, the program sought to update existing metadata forms by working through the country analysts and directly with developers and researchers. Over the course of 2016, 4 new project sites and 2 new research study forms have been added, while 11 project site forms and 6 research study forms have been updated within the last 18 months. Additionally, 33 project sites and 42 research studies have been determined as "completed" or "canceled" and no longer require updates. The total Annex IV metadata form collection on *Tethys* currently includes 84 project sites and 58 research studies. Those totals include project sites for which there is no longer gear in the water but where environmental data were collected; they are maintained in the collection to increase the overall lessons that can be learned.

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 807 papers in the last year, for a total of 3,268 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 18.1%. During 2016, fourteen reviewers provided 98 peer review comments on the content and functionality of *Tethys*; the results of the peer review help guide improvements and changes to the system. A short survey was also sent to the entire Tethys community, providing 72 responses; these results gave an idea how users interact with the website.

ANNEX IV WORKSHOPS

A one-day workshop was held on February 22, 2016 in Edinburgh, Scotland, bringing together regulators, marine energy researchers and industry representatives, to identify the key challenges within the consenting process regarding collision risk for marine wildlife with tidal turbines and to produce a coordinated action plan, providing a framework to help reduce risk and uncertainty for developers and regulators. The workshop was hosted by University of Highlands and Islands, Highlands and Islands Enterprise, Marine Scotland, OES Annex IV, ORJIP Ocean Energy and ORE Catapult. The report and action plan from this workshop are available at https://tethys.pnnl.gov/sites/default/files/publications/Collision_Risk_Workshop_Final_Report.pdf

The Pacific Region Marine Renewables Environmental Regulatory Workshop was held concurrently with 11th Annual Ocean Renewable Energy Conference in Portland, OR, USA on September 21, 2016. The workshop was held to highlight the publication of two documents that address potential environmental effects from marine renewable energy development, and that are integral to understanding how the region can move forward with permitting MRE development. The two documents: Annex IV 2016 State of the Science Report; and A Review of the Environmental Impacts for Marine Hydrokinetic Projects to Inform Regulatory Permitting: Summary Findings from the 2015 Workshop on Marine Hydrokinetic Technologies, Washington D.C., were presented to the participants. More information about the workshop is available at https://tethys.pnnl.gov/events/annex-iv-workshop-pacific-region-marine-renewables-environmental-regulatory

WEBINARS

Four webinars were held by Annex IV in 2016, each bringing together between 53 and 85 people online to listen to recent research results and plans. Each of the webinars have been downloaded and viewed hundreds of times from *Tethys*.

1. Adaptive management in the Marine Renewable Energy Industry, 27 January 2016

This webinar focused on adaptive management, and how it can be used as an effective decision making process in the face of uncertainty for the MRE industry. Speakers for this webinar included: Kim Hatfield, NOAA; Nate Johnson, ORPC; and Finlay Bennet, Marine Science Scotland.

2. Collision Risk - Understanding and Resolving the Problem in Scotland, 15 March 2016

Following the International Conference on Ocean Energy (ICOE 2016) at Edinburgh, Scotland, this webinar focused on the key challenges within the permitting/consenting processes related to collision risk. Speakers for this webinar included: Dr. Ian Davies, Marine Science Scotland; George Lees, Scottish Natural Heritage; Dr. Ben Wilson, Scottish Association of Marine Science; and Dr. Carol Sparling, Sea Mammal Research Unit.

3. State of the Science Report, 10 May 2016

After the release of the State of the Science report, this webinar was held to provide an overview of the report and serve as outreach. The speaker for this webinar was Dr. Andrea Copping, PNNL.

4. Role of Biofouling in Marine Renewable Energy Development, 12 July 2016

This webinar focused on the role of marine growth in efficiency, maintenance, hard structural integrity of marine renewable energy devices. Speakers for this webinar included: Dr. Raeanne Miller, Scottish Association for Marine Science; and Dr. Jennifer Loxton, University of Highlands and Islands.

The presentations and discussions from all 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 intended to target specific issues and interactions with high levels of uncertainty that continue to hinder the advancement of research efforts and the industry as a whole, and that are being addressed by multiple research groups worldwide.

1. Potential Risks to Larvae and Plankton from Tidal Turbines, 11 August 2016

This expert forum discussed risk to plankton, lobster and fish larvae from tidal turbines, a concern that was raised specifically in the Bay of Fundy. Dr. Anna Redden from Acadia University organized this meeting, while Dr. Andrea Copping from PNNL led the discussion, with participation from 17 other researchers and scientists.

2. Risk of Collision Between Marine Mammals and Tidal Turbines - Assessing at the Population Level, 16 August 2016

This expert forum focused on the population level assessment of collision risk of animals with tidal turbines, assessing consequences, setting thresholds, modeling population impacts, and examining regulations. Dr. Carol Sparling from SMRU Consulting led this discussion, with participation from 17 other researchers and scientists.

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

STATE OF THE SCIENCE REPORT

The culmination of Phase 2 of Annex IV was the State of the Science of environmental impacts of marine renewable energy (MRE) report. Specific chapters detail the current state of scientific understanding, identify continued data gaps and suggest research and monitoring needs moving forward for important environmental concerns. The report includes chapters on: 1) An introduction to Annex IV, 1) A Summary of the Potential Environmental Interactions Associated with the Deployment of Marine Renewable Energy Devices, 3) Collision Risk for Animals Around Tidal Turbines 4) Risk to Marine Animals from Underwater Sound Generated by Marine Renewable Energy Devices, 5) Changes in Physical Systems: Energy Removal and Changes in Flow, 6) Effects of EMF on Marine Animals from Electrical Cables and Marine Renewable Energy Devices, 7) Changes in Habitat Caused by Marine Renewable Energy Devices: Benthic Habitats and Reefing Patterns 8) Marine Spatial Planning and Marine Renewable Energy, and 9) Case Studies that Examine Siting and Permitting/Consenting of Marine Renewable Energy Devices. The final report was officially released in April 2016 and multiple presentations and briefings have occurred to help disseminate the report. In addition to the full report, short one-page summaries of each chapter were prepared, and the Executive Summary is available in seven different languages (English, Chinese, Japanese, Norwegian, Portuguese, Spanish, and Swedish).

The Full Report, Executive Summary, and one page chapter summaries are available on Tethys at: https://tethys.pnnl.gov/publications/state-of-the-science-2016

FUTURE ACTIVITIES

Future efforts will continue to focus on creating a commons around Annex IV and *Tethys* including: the continuation of the Annex IV environmental webinars and expert forums and the regular addition of new content, metadata, blog posts, and *Tethys* Blasts to continue engaging the Tethys community. Regular communication and update calls will be held with Annex IV member nation analysts to keep them apprised of Annex IV progress and upcoming activities such as: webinars and expert forums; soliciting new and updated metadata forms.

TASK 5
EXCHANGE AND ASSESSMENT OF OCEAN ENERGY DEVICE PROJECT INFORMATION AND EXPERIENCE

COORDINATOR

Robert Thresher at the National Renewable Energy Laboratory on behalf of the Department of Energy (DOE), U.S.

PARTICIPATING COUNTRIES

All Member Countries

FURTHER INFORMATION

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

OBJECTIVES

The mission of Task 5 - The Exchange and Assessment of Ocean Energy Device Project Information and Experience - is to accelerate ocean energy device project development by promoting the sharing, interchange, evaluation, and compilation of information from participating member countries.

To this end, Task 5 is sponsoring a series of workshops, bringing international experts together to contribute and exchange data that can be used to develop an assessment of the fundamental knowledge of ocean energy.

The workshops are managed and administered by the United States Department of Energy and by the National Renewable Energy Laboratory.

The United States Department of Energy has been funding the management and operational costs of this task, while each of the participating countries has been independently funding their participation in the workshops. The OES common fund supported part of the costs of the workshops.

MAJOR ACHIEVEMENTS

In 2016, one workshop was organized by the U.S. Department of Energy, hosted by the Swedish Delegate, Maria Olsson, of the Swedish Energy Agency and facilitated by Robert Thresher (US alternate) of the National Renewable Energy Laboratory and Henry Jeffrey (UK alternate) of the University of Edinburgh. The workshop was held at Brastad, Sweden on May 12, 2016.

This information exchange workshop was focused on the lessons learnt from various policies and other support measures implemented in OES member countries. Through knowledge sharing and collaborative analysis of impacts on the ocean energy sector, it is intended that lessons may be learnt from the results of these instruments, allowing future policies and support measures to be designed in a more informed and effective manner. Given the core vision and goals of the OES, the aim of this workshop was to identify ways in which policy instruments may be used to accelerate development of the ocean energy sector. Central to this goal is the need to foster significant reductions in the cost of energy supplied.

The eight presentations given at the workshop identified and analyze previously implemented policy and support measures, but also included ideas for future implementations. Following the eight brief presentations on ocean policy experience in various countries, there was a period of extended discussion in small working groups in which the participants were asked to discuss and provide a brief written response to four questions on their experience with ocean energy.

The results of the workshop are intended to provide feedback to policy makers on ideas and approaches to improve the effectiveness of future ocean energy policies.

FUTURE PLANS

The ExCo decided to keep this task open and to identify topics of common interest for organising future workshops.

WORKSHOP RESULTS

OCEAN ENERGY POLICIES: LESSONS LEARNT
SMOGEN, SWEDEN, 12TH MAY 2016

QUESTION 1

What lessons have been learnt from past ocean energy policy experience? What went well and what didn't work as well?

"Ocean energy policies that worked well were those where funding agent policies have been flexible, agents worked closely with industry, and have been responsive to their needs. In addition, an incremental approach to development at a modest scale and in collaboration with universities was identified as being productive…"

Areas where current policies were seen as not working well were where funding agencies had expectations that were too optimistic regarding the cost and time to develop ocean energy technologies. .. Due to the high expectations and short timelines some ambitious projects have resulted in failures and the lessons learned both good and bad have not been openly shared."

QUESTION 2

What recommendation would you suggest to improve on existing policies?

*"..**clear, specifically tailored policies** addressing ocean energy technology development with associated funding levels and realistic timelines. The policies should create targeted stepping stone markets and incentivize early development and deployment of ocean energy technologies to prove their viability in realistic commercial applications."*

*"The **funding needs to be flexible and tailored** to the developer's needs, and be as continuous as possible to eliminate disruptive gaps and research team disintegration."*

"..technology development should employ a step‐by‐step stage gate process for approving funding and advancement to the next stage, which is guided by a well vetted set of metrics. The timeline and funding should be realistic and well informed by past national and international experience. Failures should be anticipated because there are significant uncertainties in the ocean energy development process."

QUESTION 3

What new approaches do you recommend?

*"…**long term focus** for the ocean energy development programs with more emphasis on research and development."*

*"…**a one‐stop shop** for permitting ocean energy facilities."*

*"..**more communication**, collaboration, and data sharing to address several different technical and manufacturing challenges."*

The full report is available at: www.ocean-energy-systems.org

TASK 6
WORLDWIDE WEB GIS DATABASE FOR OCEAN ENERGY

COORDINATOR
Jochen Bard, Fraunhofer Institute IWES, Germany

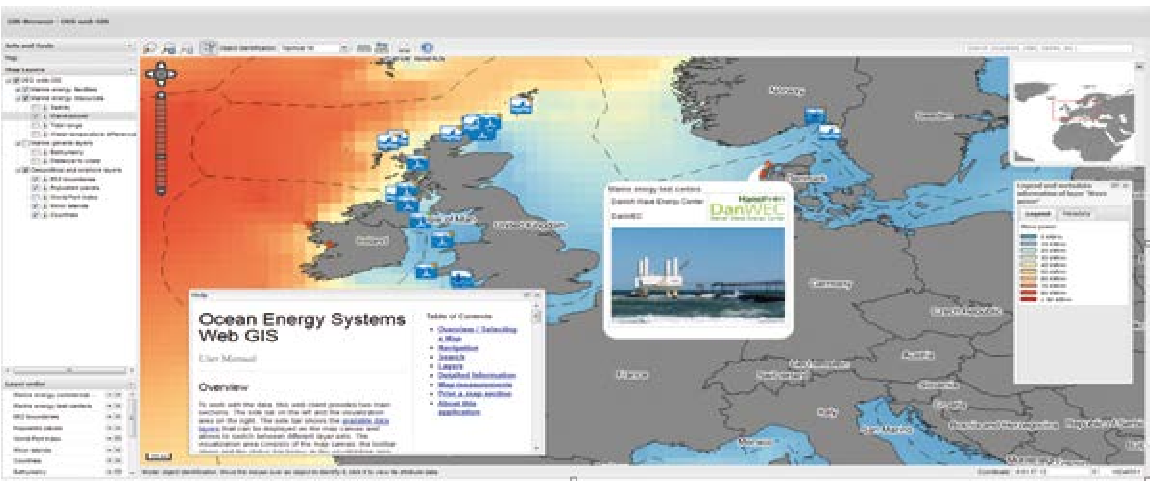
PARTICIPATING COUNTRIES
All Member Countries

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

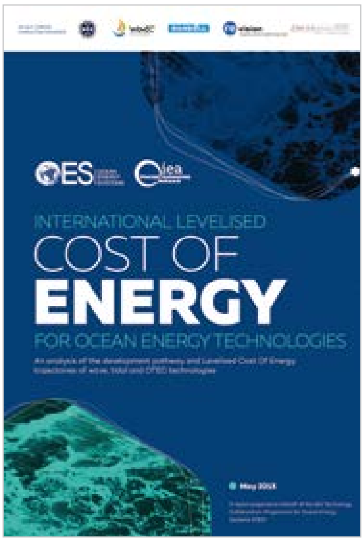
OBJECTIVE
The goal of this project is to develop and keep updated an interactive web-based GIS mapping application to give interested website visitors access to detailed global information related to ocean energy in an easy to use yet visually striking way.

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 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/

MAJOR ACHIEVEMENTS
The assessment of 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. To unlock some of these cost savings, the deployment levels of ocean energy converters will need to ramp up and projects must progress into the construction and operation phases.

This project 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. Some similarities exist among the technologies considered. Current LCOE values are very high for wave, tidal and OTEC technologies in comparison to the incumbent power generation technologies, leading to significant cost-reduction requirements in order to become competitive. Although progress has been demonstrated to date, the level of progress is not on par with expectations. The rate of deployment has been significantly slower than anticipated by some investors and policymakers.

At this stage in the development of each technology, the best available data comes from pilot projects. In conjunction with a simplified cost model, as used within this approach, the uncertainty level was expected to be in the region of ±30%, consistent with studies in other technologies both within and outside of the energy sector. There were also a number of differences between the technologies that were clear within this study. Wave energy sector development lags that of tidal stream energy, and there is an identified lack of fundamental performance and operational data to validate the early stage projections made by wave energy technology developers.

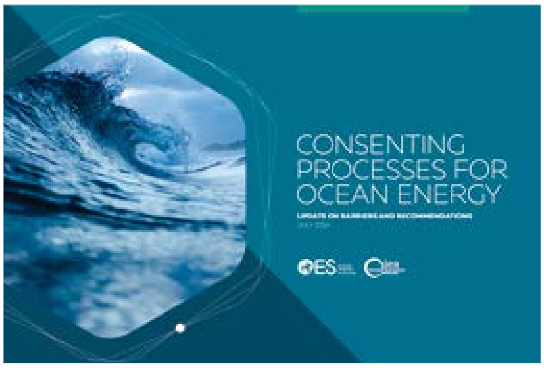
The challenges for each sector are clear. Demonstrable progress in reliable unit operation is required in order to verify and validate the cost projections that have been made within this report. High costs are intrinsic to the early stage development of technology, but clear evidence of progression down the cost curve is needed in order to restore confidence in the ability of each sector to deliver the targets that have been set. The outputs of this work have resulted in the generation of all input data required for the TIMES regional modelling, carried out by the IEA within their Energy Technology Perspectives document. By making a clear distinction among wave, tidal and OTEC technologies, the relevant parameters for each technology can allow for a more robust piece of modelling work that more truly reflects the diverse nature of these very different ocean energy technologies.

TASK 8
CONSENTING PROCESSES FOR OCEAN ENERGY

COORDINATOR
Ana Brito Melo, WavEC, Portugal

PARTICIPATING COUNTRIES
Canada, China, Denmark, France, Germany, Ireland, Korea, Mexico, Monaco, Nigeria, Norway, Portugal, South Africa, Spain, Sweden, UK and USA

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



MAJOR ACHIEVEMENTS
It is widely accepted that the ocean has the potential to become an important source of clean energy that could help drive innovation and job creation in coastal areas. Although several devices have been deployed at sea, the consenting process is still regarded as a critical barrier for industry and to future progress of the sector. The time involved in obtaining consents is of great concern to most developers as it has definite resource and economic implications for project planning. Ocean energy projects are relatively new to many regulatory bodies and are often considered under legislation developed for other sectors (e.g. oil & gas or aquaculture) which may not be ideally suited to a new technology such as ocean energy. As a way to expedite the consenting process, some countries have attempted to "streamline" their procedures so as to improve their operation.

The report "Consenting Processes for Ocean Energy" published in 2016 features information garnered from OES members. Specifically, this refers to the countries of Canada, China, Denmark, Germany, Ireland, Mexico, Monaco, Nigeria, Norway, Portugal, South Africa, Spain, Sweden, the United Kingdom and the United States of America giving the following report a wide geographic dimension.
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.
This report 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.

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/

MAJOR ACHIEVEMENTS

In 2016 an internal report "International Ocean Energy Technologies: Synergies with other Industrial Sectors" was prepared outlining opportunities for potential technology and knowledge transfer, which could provide the solutions to challenges faced by the ocean energy sector. In producing this study, over 200 organisations were contacted and over 60 one-on-one interviews were conducted. Approximately one-third of the interviewees were from the ocean energy sector, while the remainder were from other sectors including oil & gas, transport & operations, the supply chain, manufacturing, offshore wind and other renewable energy sectors.

This analysis was used to update, validate and refine knowledge regarding the barriers currently faced by the sector. For sectors similar to ocean energy, such as those operating in the marine environment, the process was designed to highlight the areas of knowledge transfer potential from more mature sectors. Responses from all organisations, particularly those involved with manufacturing, were used to uncover opportunities for technology transfer and supply chain creation.

This analysis has highlighted that to build understanding and generate interest in ocean energy, more effort to present the successes and challenges of the ocean energy sector to other industries, beyond those relating to energy, is necessary. To exploit the synergies identified, several recommendations have been made. These include:

- Increased dissemination outside the marine sector.
- Inter-industry collaboration regarding supply chains to allow feedback to be integrated into new products.
- Sharing of datasets to ensure that developers working at all scales can gather accurate data suitable to deploy larger scale technologies.
- Linking ocean energy developers with large industrial partners to reduce investor risk.
- Widening the scope of funding body calls for sub-system solutions beyond the ocean energy sector and encourage inter-industry joint bids.

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.

These results have been included in the final output of this task, which is the "**International Vision for Ocean Energy**" brochure to be released in early 2017.

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

MAJOR ACHIEVEMENTS
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. The following long-term goals were defined:

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, to: a) reduce risk in technology development, b) improve WEC energy capture estimates, c) improve loads estimates and d) reduce uncertainty in LCOE models
4. To define future research and develop methods of verifying and validating the different types of numerical models required.

A first meeting was organised in September by the Danish member, Kim Nielsen, with a number of experts on numerical modelling. The objective of this workshop was to clarify the methodology for this task and prepare a document to be discussed at the ExCo meeting as well as identifying the countries willing to participate.

Kick-off Workshop in Amsterdam, September 2016
A kick-off workshop was held on 15th September in Amsterdam with 18 participants (of which five were connected via internet), representing 10 countries and 16 organizations.

PARTICIPANTS OF THE KICK-OFF WORKSHOP IN AMSTERDAM15TH SEPTEMBER 2016

COUNTRY	ORGANISATION/COMPANY	EXPERT NAME(S)
Canada	Dynamic Systems Analysis (DSA)	André Roy[1] & Dean Steinke[1]
Denmark	Ramboll	Kim Nielsen
Denmark	DTU *(also representing ISSC2018)*	Harry Bingham
Denmark	Floating Power Plant	Sarah Thomas & Pilar Heras
Denmark	AAU & Floating Power Plant	Morten Mejlhede Kramer
France	INNOSEA	Samuel Girardin[1] & Hakim Mouslim[1]
Netherlands	MARIN	Tim Bunnik
Portugal	WavEC	Marco Alves
Spain	Tecnalia	Imanol Touzon Gonzalez
Sweden	Chalmers University	Claes Eskilsson
UK	Queens University of Belfast	Paul Lamont-Kane
UK/Ireland	Wave Venture	Ronan Costello
USA	NREL	Yu, Yi-Hsiang
USA	Sandia National Laboratories	Kelley M Ruehl[1]

Via internet [1]

It was agreed in the workshop to start with simple problems in order to establish effective co-operation between participants. Therefore, the group decided to analyse initially a 1-degree of freedom case of a floating sphere. The methodology is expected to be extended to include other geometries (e.g. cylinders, flap-type, a fixed OWC chamber, etc). These results will be presented and discussed in the next workshop expected to be held by mid-March 2017.

Work Program

The proposed work plan includes the following activities:

Task 10.1 Define verification strategies and validation practice and metrics to be used, when comparing analytical, experimental and numerical results. The metrics should consider:

- Energy generated and power output;
- Device motions, position, velocity and acceleration;
- Measurement and simulation accuracies;
- Repeatability and reproducibility of measurements.

Task 10.2 Develop and identify suitable analytical models of wave energy converters.

Task 10.3 Identify a few base line cases for a first comparison between numerical simulations based on a limited suite of experimental test cases.

Task 10.4 Analyse the simulation results based on the metrics from Task 10.1 and develop comparison charts for validation purposes; compare and evaluate the numerical simulation results and evaluate the simulation results with respect to experimental data.

Task 10.5 Discuss the need, practicality and cost of obtaining additional experimental test data for model validation and making written recommendations to the ExCo and the technical community.

Task 10.6 Develop new experimental data sets for i) Innovative concepts and ii) device archetypes that are lacking in currently available experimental data

Task 10. 7 Dissemination

TASK 11
OCEAN THERMAL ENERGY CONVERSION

COORDINATOR

Yasuyuki Ikegami, Saga University, Japan

PARTICIPATING COUNTRIES

China, France, India, Japan, Republic of Korea, Singapore and The Netherlands

BACKGROUND

In recent years, the United States, France, Korea, Japan and other countries have been developing a few OTEC demonstration projects aiming 1 MW - 10 MW range. In 2014, DCNS has obtained €72 million from the European Union for a 10 MW project in Martinique and have announced expected operation in 2018. There are great expectations for OTEC as compared to other renewable energies due to its stable power generation characteristics, multiple use (cooling, desalination, hydrogen production, etc.) and job creation.

OTEC requires very large economies of scale compared with other marine energy technologies. Economically, a 10 MW scale plant is expected to have an electricity cost of $200/MWh, while a 100 MW plant or larger is expected to cost $100/MWh, which would require a large project with initial investment in excess of $300 million. A 1 MW plant is expected to have an electricity cost of $300-400/MWh, however, considering multiple use such as utilization of cold deep sea water and desalination, a cost of $200/MWh or less is expected. In this way, the characteristics of cost evaluation and operation of OTEC are very different from other ocean energy technologies.

On the other hand, for the application and promotion of OTEC it is necessary to pay careful attention to the use of large amounts of seawater in terms of protection of the marine environment. Benefits such as significant carbon dioxide reductions and improvement of fishery resources through cold water use are expected, however, it is important to perform assessments such as the impact of nutrient enrichment on the ocean.

To investigate issues related to large scale OTEC development it is important to first understand the potential resource. Therefore, an initial task has been proposing aiming to study and understand the OTEC potential and status around the globe.

OBJECTIVES AND WORK

The overall work lead by Japan will be 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 will be produced as a first step to further define a full work program under Task 11. 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.

04.

INTERVIEW TO OPEN SEA TEST CENTRES

INTERVIEW WITH:

OLIVER WRAGG

COMMERCIAL DIRECTOR
EMEC

TONY WRIGHT

GENERAL MANAGER
FORCE

SAMANTHA QUINN

OPERATIONS MANAGER
NNMREC

YAGO TORRE-ENCISO

TECHNICAL DIRECTOR
BIMEP

TAKAAKI MORITA

DIRECTOR
Marine & Environmental Industry Development Division,
Industry & Labor Department Nagasaki Prefectural Government

EMEC - UK

OLIVER WRAGG . EMEC COMMERCIAL DIRECTOR

1 What was the motivation and the driving forces to build The European Marine Energy Centre (EMEC) Ltd, and what milestones were set up for its development? To date, how much funding (public and private) has been granted for its creation and operation?

Established in 2003, The European Marine Energy Centre (EMEC) Ltd is the first and only centre of its kind in the world to provide developers of both wave and tidal energy converters with purpose-built, accredited open-sea testing facilities. EMEC was established to simultaneously accelerate the development of wave and tidal energy technology, whilst also stimulating economic development in coastal communities.

In 2001, the UK House of Commons Science and Technology Committee recommended that the Orkney Islands in Scotland would be ideal for becoming the home for the European Marine Energy Centre, due to strong wave and tidal resources, combined with energy, environmental and maritime skills in the local community. The wave site at Billia Croo opened in 2004, hosting the Pelamis P1 which became the world's first floating wave energy device to generate electricity to the national grid. In 2006, the tidal test site at Fall of Warness opened, which just two years later saw client OpenHydro become the first tidal turbine to generate electricity to the grid in the UK. 13 years later EMEC has now hosted 17 wave and tidal energy clients (with 27 marine energy devices) spanning 9 countries.

To date EMEC has received in the region of £36 million of public investment from a combination of local, regional, national, and European sources. These include Orkney Islands Council, Highlands and Islands Enterprise, Scottish Government, UK Government, European Regional Development Funding, and the European Commission. Since 2011 EMEC has sustained financial independence.

2 It is recognised that test centres can be instrumental in proving the technology can work in challenging marine environments. What other benefits do you see for developers and also for local/regional communities?

There are so many benefits it is sometimes hard to know where to start. From a technology developers' perspective, the major benefit has to be the removal of barriers to deployment, notably consenting, data collection, stakeholder engagement and grid regulation. As EMEC is an independently accredited test laboratory and verification centre, there is also great benefit that technology developers can avail of by securing independent test results and performance verifications of power performance and other key technology claims. These reports can help secure future finance and investment to move technology towards commercialisation. They can also aid certification and help to reduce insurance costs.

For local and regional communities, a test centre can be the catalyst for the development of a new high value, highly skilled industry, creating much needed jobs and economic development in rural coastal communities.

EMEC also provides a shop window to the industry. Every year we host more than 300 visitors from around the world. These visitors are a combination of governments, investors, research organisations, utilities and supply chain companies from around the world.

For local and regional communities, a test centre can be the catalyst for the development of a new high value, highly skilled industry, creating much needed jobs and economic development in rural coastal communities. These are particularly important as much of the skills required to support ocean energy are often already present in these communities, e.g. offshore operations knowledge gained by fishermen. Test centres also benefit the local communities as they provide an area where concerned local stakeholders, e.g. fishermen, ferries and other sea users, can view first hand the limited impact that ocean energy has on the environment in which they operate. To put the economic impact of EMEC into context, since it was created in 2003, EMEC has generated a gross value added to the UK economy of £249.6 million, with 3,801 full-time equivalent (FTE) job years so far, according to an economic impact assessment commissioned by Highlands and Islands Enterprise. This equates to 380 permanent FTE in the UK economy over the course of 10 years, 149 of which have been based in Orkney.

3 For ocean energy in general, do you think test centres have a role to play on giving international visibility to the sector? Do you see improvement potential in this respect, and have suggestions?

EMEC has always seen one of its key roles as being a shop window for ocean energy, not just in the UK but globally. At the end of the day, technology cannot be proven unless it is deployed and to coin a phrase from the EMEC Managing Director we need to "get metal wet". We can all see pictures and images of technology in the water at conferences, events and on websites, but based on the number of visitors EMEC receives each year, it can definitely be concluded that seeing is believing.

One area that EMEC is working to improve is how we work collaboratively with our clients and innovation partners, notably at conferences, we are seeing our role more to help SME companies promote their work to wide audiences with real life examples. EMEC has also hosted a European Ocean Energy day in 2014 where we held an open doors event and hosted multiple members of the European Commission. Being able to communicate the real-life challenges and opportunities to key stakeholders is an important role of a test centre. EMEC hopes to be able to replicate the success of the 2014 European Ocean Energy day and believes that it is important that other test centres around the world actively engage with their relevant public stakeholders to demonstrate success in ocean energy.

4 There are several test centres around the world, how do you see the possibility of knowledge sharing between these test centres? Apart from technology-specific details that are usually under non-disclosure, what information could be shared to support the sector?

EMEC's vision is to create a globally successful marine energy industry which undoubtedly requires knowledge sharing and collaboration. To this end EMEC has taken an active lead in trying to improve the coordination between international test centres, notably by the creation of the International Wave and Tidal Energy Research Sites (International WATERS). International WATERS is a collective of developed and developing open ocean test facilities around the world. It has met three times in the past three years and future events are planned. The objective is to share learning between test centres so that lessons can be learnt and collaborations formed.

As the world's first test centre of its kind, EMEC has experienced a huge learning curve and wants to support other test centres by exporting this knowledge, reducing the duplication of work or any mistakes.

In terms of priority, EMEC consistently finds that collaboration in the areas of testing and standards is beneficial. One only has to travel overseas and attempt to plug in a computer to experience why this is important. Every country established their own standards for plugs and sockets in isolation and the end result is pointless diversity of detail in the simple plugs throughout the world.

Marine energy devices are no different. In time, wave and tidal technologies will find their markets in dozens of countries and EMEC wants this to be as easy as possible both for the technology developers at EMEC and the ultimate customer here or overseas. We want a wave or tidal device which is certified at EMEC to be immediately marketable in any country, without expensive and time consuming re-validation.

The establishment of common global standards will be central to this. That is why, for more than a decade, EMEC has been at the very forefront of the development of international standards, having coordinated the development of a suite of 12 industry guidelines, 6 of which are being used as starting points for the first international standards for marine energy and are being developed as technical specifications.

> *In time, wave and tidal technologies will find their markets in dozens of countries and EMEC wants this to be as easy as possible both for the technology developers at EMEC and the ultimate customer here or overseas.*

Critical to this, I believe, is the development of a standard approach to performance and resource assessment. If technologies invented in the UK and developed here at EMEC are to become established as global products, then it is vital that each international test centre uses the same common standards so investors can compare results from one centre with results at another. The establishment of a global network of test sites will lead to a community of interest with common standards and approaches to the business of marine energy. Common standards, developed by worldwide experience, can only help accelerate the deployment of wave and tidal technologies.

Each country has its own unique conditions, both physical and political, and exploring these challenges simultaneously will enable marine energy technologies to colonise these optimum niches more rapidly than if tackled in isolation.

The marine energy industry is developing close to the limits of understanding of the interactions between devices and the energetic and biologically rich marine environments in which they are deployed. Research is, therefore, essential to the future evolution of the industry.

The FORESEA project (Funding Ocean Renewable Energy through Strategic European Action) is another excellent example of how test facilities can work together. The collaboration between EMEC, Smart Bay (Ireland), SEM-REV (France), Tidal Testing Centre (Holland) and Ocean Energy Europe (Belgium), is working to provide dedicated support packages to technology developers looking to get kit in the water. Through the FORESEA project we have seen first-hand how test centres can work collaboratively to assist the industry. Another example of collaboration and knowledge sharing is the Marinet project which is now being followed by Marinet2.

5 Would you like to mention any key lessons from your experience over the operation of the test centre? Have expenses kept reasonably within foreseen limits, or were there any major unforeseen challenges?

There have been an incredible number of lessons learned along the path of EMEC's development – the importance of planning survey data, contracting strategies for design and construction, commissioning and handover of assets. Cables have been installed using a number of different techniques (vessel mounted carousel, barge and dynamically positioning (DP) vessel). Key to being able to maintain test infrastructure and deliver client's requirements is operational management. EMEC's Operations team are involved throughout the client lifecycle supporting the developers through site access, data collection, and electrical systems. For example, installation of devices at the tidal test site at the Fall of Warness is dictated by tidal conditions. The period for installation activities, due to the favourable tidal windows, can be considered by all developers for the installation of their device leading to instances where more than one developer can be working on site at the same time.

The marine energy industry is developing close to the limits of understanding of the interactions between devices and the energetic and biologically rich marine environments in which they are deployed. Research is, therefore, essential to the future evolution of the industry. It is important to EMEC that environmental monitoring undertaken at its test sites is informed and guided by expert input. EMEC is therefore keen to ensure that its environmental monitoring programme should be guided by Regulatory and expert input. It must identify the key environmental sensitivities at the site and aim to assess the potential for wave and tidal energy devices to cause negative effects or impacts on this receiving environment.

From an early stage EMEC recognised the need to develop a strong Health & Safety (H&S) management system that met international standards. Similarly, the need for exemplary environmental management was recognised. As EMEC moved into collection of data and established capability to manipulate and report test and other data, the need for quality assurance (QA) management became more acute. The idea evolved that these management systems had a great deal in common so that there was logic in integrating the management systems - hence the EMEC Integrated Management System (IMS) approach was adopted.

Working within ocean energy over the past 14 years EMEC has seen many evolutions within the industry. The biggest challenge has been to stay responsive to industry needs – sites, equipment and systems have been reconfigured over time in response to demand. This is a natural consequence of the space we inhabit – on the edge of innovation. Examples of this relate to the length of contracts that we are providing, we are seeing more tidal technology developers seeking opportunities for pre-commercial array demonstration. From the wave energy industry, we are seeing a need to assist technology developers at earlier TRLs, for example the Horizon 2020 WaveBoost project we are working on with CorPower.

In terms of delivering the infrastructure, EMEC has successfully project managed the continuous evolution of the test centre. This has been achieved through careful planning, project management and consciously having one eye on the future to anticipate the needs of the industry.

The most valuable learning however, is the domain of the technology companies who are testing their devices – what we can say is that the value of real sea testing is critical to any technology development pathway. Only by proving performance in a real sea environment can developers truly progress to commercial projects. Verified performance data from open-water testing will continue to build confidence amongst the investment community and help developers bring their concepts to a global clean energy market.

FORCE - CANADA

TONY WRIGHT . GENERAL MANAGER, FORCE

1 What was the motivation and the driving forces to build *FORCE* and what milestones were set up for its development? To date, how much funding (public and private) has been granted for its creation and operation?

FORCE was established to serve as demonstration facility for in-stream tidal energy technologies in an effort to assess whether tidal energy can play a role in Nova Scotia's energy future. Nova Scotia has strong motivations: imported fossil fuel is responsible for up to 75% of the province's electricity generation.

FORCE was established by contributions from the Government of Canada, the Province of Nova Scotia, and Encana Corporation. To-date, FORCE has received $25 million from the Government of Canada and the Government of Nova Scotia has committed $11 million. In addition, FORCE's 'berth holder' companies make a one-time capital contribution to FORCE of $1 million and pay berth fees to support ongoing operations, research, and monitoring.

Milestones:

- FORCE received its Environmental Assessment Approval in 2009 and was home to Canada's first deployed in-stream tidal turbine that year
- FORCE completed the construction of its onshore facility in 2011, onshore substation in 2012, subsea data cable installed in 2013, and four subsea electrical cables completed in 2014. The first grid-connected device was deployed in November 2016, by Cape Sharp Tidal Ventures.

2 It is recognised that test centres can be instrumental in proving the technology can work in challenging marine environments. What other benefits do you see for developers and also for local/regional communities?

For Nova Scotians, tidal energy provides clean electricity to Nova Scotians (tidal energy more predictable source of renewable electricity). The FORCE project also provides local economic benefits: research, construction, hospitality and building on existing ocean technology expertise. The FORCE project alone has used over 300 suppliers, 90% of which come from Atlantic Canada.

FORCE's Visitors Center also serves as an eco-tourism opportunity. Since 2011, FORCE has welcomed over 24,000 visitors. As a test center, FORCE provides a lower cost option for developers by having infrastructure and an Environmental Assessment Approval in place. For the scientific community, the project is responsible for advancing the understanding of the Minas Passage in the Bay of Fundy in terms of both physical and biological characteristics, it has also been an opportunity for the region's ocean sensing community, providing a high flow testing ground for acoustic and optical instrumentation and deployment and recovery methods.

> *To-date, FORCE has received $25 million from the Government of Canada and the Government of Nova Scotia has committed $11 million. The FORCE project alone has used over 300 suppliers, 90% of which come from Atlantic Canada.*

3 For ocean energy in general, do you think test centres have a role to play on giving international visibility to the sector? Do you see improvement potential in this respect, and have suggestions?

An opportunity to combine infrastructure, supply chain, research, monitoring and engagement is both efficient and effective, and has the potential to raise the overall awareness/profile of the sector.

4 There are several test centres around the world, how do you see the possibility of knowledge sharing between these test centres? Apart from technology-specific details that are usually under non-disclosure, what information could be shared to support the sector?

Yes, test centers (esp. at this early stage) must work together. FORCE has had an ongoing relationship with EMEC in Scotland for years. Right now, we're looking at the difference in corrosion and underwater behaviour of marine coatings on either side of the Atlantic Ocean. This cooperation provides an opportunity to learn lessons based on one another's experience, share resources, and support innovations. Perhaps the most vital information sharing is around understanding and responding to potential environmental effects. To secure both public and regulatory support, it's vital that all test centres target areas of uncertainty, monitor, and share results. There are other areas – such as deployment, mooring, O&M, cable interconnection – that will all benefit from the development of standardization and best practices, but many of these areas understandably still remain under IP protection as they evolve.

5 Would you like to mention any key lessons from your experience over the operation of the test centre? Have expenses kept reasonably within foreseen limits, or were there any major unforeseen challenges?

There are a number of challenges working at our site. First, the extreme high flows. We have managed to build our facility within budget, but this required a very active evolution in understanding and retiring marine operational risks. Smaller is better, but every operation requires safety and redundancy – understanding what's possible has taken many hours of trial and error on the water. Ideally, you want to develop a group of marine suppliers that can be involved frequently and repeatedly – you can never get enough practice deploying and recovering marine assets in an environment like ours.

The other major lesson is level of engagement. While we spent considerable effort to build relationships within the area where we work, the project faced a legal challenge from lobster fishers that were approximately 100km away. It's vital that the broader marine community be engaged regularly and comprehensively during all stages of the project, both to share project-specific information, as well as hear their concerns. The industry will only work if it can co-exist with other users, and so fishers, First Nations, and other communities with a longstanding connection to the marine system need to be meaningfully involved – not only at the start, but at every stage.

Finally, as mentioned earlier, there must be a concerted effort to collect, interpret, and share data related to any environmental effects. While the work done to date has been encouraging, far more needs to be collected. The public and regulators will need convincing evidence that any effects are both known and acceptable if the technology is to move to larger-scale.

NNMREC - USA

SAMANTHA QUINN . OPERATIONS MANAGER, NNMREC

1 What was the motivation and the driving forces to build NNMREC and what milestones were set up for its development? To date, how much funding (public and private) has been granted for its creation and operation?

In 2008, the United States Department of Energy (DOE) invested $6.25 million to set up the Northwest National Marine Renewable Energy Center (NNMREC) with a variety of research and testing objectives, one of which directed the Center to develop integrated test facilities for marine energy. Advancing the knowledge and supporting the deployment of marine renewable energy technologies is the mission of NNMREC and its world class facilities that have been developed under the Pacific Marine Energy Center (PMEC) moniker.

In 2012, DOE allocated an additional $4 million to begin developing PMEC – SETS (South Energy Test Site), planned as a deep-water test facility off the coast of Newport, Oregon. Further funding was allocated again in 2015 and 2016 for just over $11M in funding from federal and non-federal sources towards the PMEC-SETS development.

In 2016, NNMREC was awarded up to $40 million from the DOE to complete PMEC-SETS. The site will have 4 grid-connected berths, which can accommodate up to 20

Advancing the knowledge and supporting the deployment of marine renewable energy technologies is the mission of NNMREC

WECs simultaneously, exporting up to 20MW of electricity to the grid. This pre-permitted site will allow for technology developers to focus on the challenges of operating in open ocean environments.

2 It is recognised that test centres can be instrumental in proving the technology can work in challenging marine environments. What other benefits do you see for developers and also for local/regional communities?

NNMREC and PMEC provide an array of technical expertise and we have also worked conscientiously to build a strong relationship with the local and regional communities. PMEC sets is in an evolutionary state and we require this symbiotic relationship in order to gain the expertise of the community. The establishment of PMEC-SETS will provide further opportunities for developers to engage with the local community including engineering companies, vessel operators, port operators, divers, fishermen, who can all provide their expertise of the Oregon coast and ocean waters. This will also introduce more opportunities of involvement and potential jobs for the local and regional communities.

3 For ocean energy in general, do you think test centres have a role to play on giving international visibility to the sector? Do you see improvement potential in this respect, and have suggestions?

Currently, there are only a few test centres in the world with open-ocean capabilities, and the other wave laboratories are fairly unknown to people outside of the local communities. By building more facilities, giving more opportunities for developers around the world to test in a variety of sea-states, the industry will see more improvement and the potential for a commercial industry sooner than projected.

Further, as NNMREC and PMEC is currently experiencing an influx of inquiries about the facility and about ocean energy in general, this highlights the idea that test centres do give a higher profile to the sector. The test facilities indicate that the sector is moving in a forward direction and that there is increasing confidence in the technologies.

4 There are several test centres around the world, how do you see the possibility of knowledge sharing between these test centres? Apart from technology-specific details that are usually under non-disclosure, what information could be shared to support the sector?

Knowledge sharing is definitely something that continues to be a delicate topic within marine energy research, especially with regard to technology. However, NNMREC, and PMEC, have partnered with EMEC in the development of the PMEC-SETS facility. This will help in the development of the PMEC-SETS site by gaining insight and an understanding of the lessons learned to insure that this new facility will meet the needs of the industry and provide the industry with new resources within facilities. Sharing this knowledge about operations, maintenance, business development and other key aspects of test centres will lead to better standardization internationally.

Further, understanding the capabilities of other wave and tidal testing laboratories help to provide the industry on best guidance of where to test their technologies.

Sharing this knowledge about operations, maintenance, business development and other key aspects of test centres will lead to better standardization internationally.

5 Would you like to mention any key lessons from your experience over the operation of the test centre? Have expenses kept reasonably within foreseen limits, or were there any major unforeseen challenges?

In addition to the PMEC-SETS test facility, NNMREC also operates the PMEC- NETS (North Energy Test Site). This is non-grid connect site off the coast of Newport, Oregon where developers can either connect to NNMREC's mobile ocean instrumentation test buoy or conduct self-contained tests. NNMREC has realised that having a test site without multiple berths is very expensive in terms of O&M costs and has not been utilised as much as originally anticipated.

BIMEP - SPAIN

YAGO TORRE-ENCISO . BIMEP TECHNICAL DIRECTOR

As mentioned above test centres such as BiMEP help developers to save money and time. Every developer that wants to carry out open sea trials would need to go through the whole licensing procedure, buy a cable, lay it, connect it into the grid, etc. This means huge amounts of time and money.

1 What was the motivation and the driving forces to build Bimep, and what milestones were set up for its development? To date, how much funding (public and private) has been granted for its creation and operation?

The Biscay Marine Energy Platform, BiMEP, was conceived as a project based mainly on three pillars:

Today, the need for countries to be more energy independent, and to have a more diverse energy mix, is clear. Consequently, most are establishing renewable policies to this end. On a regional level, The Basque Country is a small and energy dependent region with an increasing energy demand. In some way they want to switch into renewables and in this attempt several of them have focused on marine renewable energy, more precisely in wave energy.

Besides, traditionally the Basque Country is a highly industrialized region. Talking about the Basque energy industry, it consists of a big number of companies with an important overall turnover, huge spending in R&D and big international business and, as a coastal country, the Basque shipyards also show relevant figures. As a consequence it can be said that the region had a strong enterprise looking forward to new challenges.

With all this in mind the Basque energy Agency, EVE, began to look for different options. They realised that off the Basque coast there is very good wave energy resource and started to assess the wave energy market coming to the conclusion that there was actually no market but a big number of different and divergent project ideas far away from commercialisation and that the sector needed to be pushed forward.

Taking into consideration that all those projects would need to be tested in open sea conditions to demonstrate their correct functioning and survivability, EVE decided to construct an infrastructure to acquire those marine energy devices sea trials helping the developers to save money and time in their long way from conception to commercialisation.

BiMEP was developed as a research infrastructure for the demonstration and validation of marine renewable energy devices with the target of positioning the Basque Country and Spain as international marine energy leaders and creating a technological, industrial and social sector around this energy.

To carry out the BiMEP test centre, a public investment close to 20 M€ was made, the principal investor being the Basque Government and the rest of the funds coming from the Spanish Government and the European Commission.

2 It is recognised that test centres can be instrumental in proving the technology can work in challenging marine environments. What other benefits do you see for developers and also for local/regional communities?

As mentioned above test centres such as BiMEP help developers to save money and time. Every developer that wants to carry out open sea trials would need to go through the whole licensing procedure, buy a cable, lay it, connect it into the grid, etc. This means huge amounts of time and money. When using a test site most of these expenses are reduced or even vanished. For instance, BiMEP is a pre-permitted test site which can be translated into minimum red-tape and BiMEP doing all the reporting with local and national authorities. So as to have one order of magnitude, the licensing procure of BiMEP lasted 5 years and the time needed by a technology developer from the information to the authorities until their answer is less than three months. Besides, the test site user would only need to pay the test centre fee saving the money from cable purchase, laying and connecting expenses.

Surviving to open sea test campaigns and proving the technology can work in harsh marine environments make developer projects become more credible being more susceptible of attracting private investment. Normally developers follow a phase project development that guarantees the technology readiness level and limits and reduces risks as much as possible. One of the final steps before commercialisation is open sea testing and as a consequence, succeeding to this makes investors more confident favouring the decision of investing into the project.

Another benefit the construction of a test centre brings to local and regional communities is the creation of a new economic activity that can generate new employment in the test centre surrounding area. Sometimes new employees would be directly hired by the testing infrastructure and some other times they would be subcontracted. The latter is the case of BiMEP. Its philosophy is that if there are already companies that have the skills to carry out the different works we need to develop we subcontract them. Consequently, they acquire knowledge and knowhow that they could use in the future wherever it is needed. This meets one of our main targets which is to consolidate companies in the Basque Country as leaders in the field.

3 For ocean energy in general, do you think test centres have a role to play on giving international visibility to the sector? Do you see improvement potential in this respect, and have suggestions?

The ocean energy sector is crowded with hundreds of different ideas but it is true that there are only a few projects that are being tested in open sea conditions. These test are usually carried out in the test sites spread around the world and the media of the different countries transform this information into a piece of news spotlighting the ocean energy sector. Every time a test centre acquires a test campaign, this becomes a piece of news that shows that the sector has made another step forward getting closer to a real market.

4 There are several test centres around the world, how do you see the possibility of knowledge sharing between these test centres? Apart from technology-specific details that are usually under non-disclosure, what information could be shared to support the sector?

Sharing knowledge among the different test centres is desirable but difficult to accomplish. Those that have been operating for several years usually don't want to lose their advantage before those that are already starting their operational phase. In any case, it would be interesting to share the lessons learnt during the different phases of construction and operation without making these test centres lose their competitive advantages. Besides, regarding the environmental aspects, almost every test centre has to carry out an environmental surveillance plan to assess the possible impacts that their activity could have in the surrounding environment implying large and expensive surveys. Some of these studies would be specific for the assessed area but some others would show results that could be extrapolated to other areas or test centres. It seems to be a good idea, in order not to expend twice money and time studying the same aspects, to develop those "common" surveys among the different test centres, sharing the results and stablishing them as a basis for future developments.

5 Would you like to mention any key lessons from your experience over the operation of the test centre? Have expenses kept reasonably within foreseen limits, or were there any major unforeseen challenges?

BiMEP was inaugurated in July 2015 and since that moment some ocean energy components and equipment have been tested. This last October, the first wave energy converter, the MARMOK-A of Oceantec was installed and connected to the grid. As a result we are just beginning to gain experience over the operation of our test centre.

Regarding the viability plan, it can be said that BiMEP has kept the expenses within foreseen limits as we have not faced major challenges up to the moment.

Almost every test centre has to carry out an environmental surveillance plan to assess the possible impacts that their activity could have in the surrounding environment implying large and expensive surveys. Some of these studies would be specific for the assessed area but some others would show results that could be extrapolated to other areas or test centres.

NAGASAKI AMEC - JAPAN

TAKAAKI MORITA . DIRECTOR - MARINE & ENVIRONMENTAL INDUSTRY DEVELOPMENT DIVISION, INDUSTRY & LABOR DEPARTMENT NAGASAKI PREFECTURAL GOVERNMENT

1 What was the motivation and the driving forces to build "Nagasaky AMEC", and what milestones were set up for its development? To date, how much funding (public and private) has been granted for its creation and operation?

Major motivation for Nagasaki Prefecture is to promote ocean renewable energy industry in order to revitalize local economy and increase employment opportunities as well as to accelerate development of ocean renewable energy technology and contribute for realization of low carbon society. Currently final business plan is under preparation.

Nagasaki Prefecture has budgeted public fund for the operation planning of the test site and the operation of one stop service provider as well as for research of wind and tidal resources at the site. At the same time, private local NPO has generated own fund for its own operation and the said NPO has been awarded by Nagasaki Prefecture for the above-mentioned planning works, operation and research works. In addition to that, the tidal power developer has secured competitive funding from the central Government.

2 It is recognised that test centres can be instrumental in proving the technology can work in challenging marine environments. What other benefits do you see for developers and also for local/regional communities?

Nagasaki Prefecture is planning to provide the opportunity for the developer to test cost effective method of installation and O&M in real ocean state conditions which are crucial to reduce LCOE and to provide with the required metocean data for business planning. For local communities, it is planning to provide the opportunity to learn special technology and method for operation of ocean renewable facility and increase business opportunity significantly.

3 For ocean energy in general, do you think test centres have a role to play on giving international visibility to the sector? Do you see improvement potential in this respect, and have suggestions?

Yes, certainly. Important role for the test centres which needs to be improved might be the real data correction for environmental impact and safety.

Nagasaki Prefecture is planning to provide the opportunity for the developer to test cost effective method of installation and O&M in real ocean state conditions which are crucial to reduce LCOE

4 There are several test centres around the world, how do you see the possibility of knowledge sharing between these test centres? Apart from technology-specific details that are usually under non-disclosure, what information could be shared to support the sector?

Already knowledge sharing activities are started among the test centres like Water workshop organized by EMEC. Possibly information on environmental impact, bio-fouling affect and the method of co-existence with fishing industry in different ocean condition/area could be shared.

5 Would you like to mention any key lessons from your experience over the operation of the test centre? Have expenses kept reasonably within foreseen limits, or were there any major unforeseen challenges?

As we have not yet started real operation, any challenge might be found through further operation phase. However, we trust that it is important to maintain good relationship with local stakeholder such as fishermen, residents and other local authorities concern at any time.

BELGIUM

LUDOVIC MOUFFE, JULIEN DE ROUCK, TIM VERBRUGGHE *University of Ghent*

INTRODUCTORY NOTE

Since Belgium only has a moderate wave and tidal climate, the ocean energy activities are mainly focused on Research & Development rather than deploying commercial ocean energy systems. However, because of the mild climate, the Belgian offshore zones can function as a testing platform for smaller scale prototypes. In the past, projects like FlanSea and Laminaria have tested device prototypes at the Harbour of Ostend. In 2016, no new test campaigns were performed, but there is an interest to extend the existing site with more infrastructures to be compatible with more device types for wave and tidal energy.

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. This share has been growing steadily in the last year. 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.

REGULATORY FRAMEWORK

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 and banks. 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 construction of a new coastal and offshore basin has been given green light by the Flemish Government. 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.

The **FlanSea project** (2010-2013) aimed at designing and developing a wave energy converter for low to moderate wave energy in the Belgian part of the North Sea (and other moderate wave zones). The project partners were DEME blue energy, Cloostermans, Harbour of Ostend, Electrawinds, Spiromatic, Contec and 4 research groups from the University of Ghent (coordinator). The project has been partly funded by IWT (Flemish Agency for Innovation by Science and Technology). The FlanSea prototype device (1/2 scale) of 4.4 m diameter, 5 m height and 25 tonnes weight was commissioned outside the Harbour of Ostend in July 2013. The sea test ended in December 2013. Results have been analysed within PhD scholarships and master theses. The plans and intentions for FlanSea II are currently under development.

FlanSea device (1/2 scale) at sea (Flanders Electricity from the sea; www.flansea.eu)

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 Power Take Off (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 for optimal conditions in smaller, more common waves. This not only results in a lighter, cheaper and more effective device, it also results in a very high capacity factor.
Over the last year a fully functional 1:4 scale prototype has been tested at the sea testing site in 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 that have an energy content of 46 times the waves needed to produce nominal power. Due to the storm pro-

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

tection strategy strains and forces on the device and moorings were 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.
In 2015, a new research project into a novel PTO type started. Cofely Fabricom and Ghent University partnered up and managed to obtain national and international (HIE-WES) funding. Their concept focuses on delivering high power quality, by transforming the oscillatory wave motions into a steady, one-directional rotation of the generator axis. The project consists of a detailed numerical study and the construction of a laboratory test set-up. In 2016, the project was finished successfully and the technology proved to be promising. Further funding will be requested to test the technology at a larger scale.

TECHNOLOGY DEMONSTRATION

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.

PLANNED DEPLOYMENTS

Depending on the results of the FlanSea I project, a possible continuation is under investigation. In this FlanSea II project the emphasis is on the development, which involves deployment of one or multiple wave energy convertors of bigger scale and/or alternative for the Power Take-Off.
Laminaria is planning a deployment at the EMEC test site in Orkney, Scotland, in 2017 (LAMWEC project). The aim is to create a win-win situation by supplying the Scottish grid with clean reliable energy and creating employment in Flanders in the development and construction of the devices.

CANADA

MONIKA KNOWLES AND GHANASHYAM RANJITKAR *Natural Resources Canada*

INTRODUCTORY NOTE

The Canadian marine renewable energy sector progressed steadily in 2016, while achieving some significant milestones for the Canadian industry. Notably, the first grid connected tidal turbine was deployed at the Fundy Ocean Research Centre for Energy (FORCE). FORCE experiences water speeds up to 5 m/s on ebb and flood tides.

Canada is fortunate to have plentiful resources available in tidal current, river currents (hydrokinetic) and wave energy across the country. Canada is well positioned to support the development of this industry with its three open-sea test sites for tidal current (FORCE), river hydrokinetic (Canadian Hydrokinetic Turbine Test Centre (CHTTC), and wave energy (Wave Energy Research Centre). Canada's opportunity in this industry is great; as such, Canada has been working at the national level as well as the provincial level to support this industry to ensure that Canada is successful in the development and deployment of marine renewables.

The Canadian marine renewable energy sector has continued to develop supportive tools to assist technology developers and project developers to advance their technologies. In 2016, many new resources became available, such as the Supply Chain database, a map of Canadian clean energy resources and projects, and a tidal energy atlas for Nova Scotia. Canada has also continued to excel on understanding the marine resource through the West Coast Wave Initiative (WCWI), for their advanced wave measurement and mapping technologies and skills, and understanding sustainable tidal energy development through the Acadia Tidal Energy Institute (ATEI). Natural Resources Canada (NRCan) and National Research Council (NRC) are continuing to work collaboratively to understand the detailed extractable resource, array configurations, and the potential market opportunities of Marine Renewables in Canada.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The Canadian Marine Renewable Energy Technology Roadmap establishes targets for the Canadian sector. The roadmap, published in 2011, identified long term targets for the Canadian sector to contribute to projects totalling 250 MW by 2020, and 2 GW by 2030 for installed in-stream tidal, river hydrokinetic and wave energy generation.

Marine renewable activities are taking place across Canada; however, the most progress is taking place on the Atlantic coast in the province of Nova Scotia for tidal energy. Nova Scotia's Marine Renewable Energy Strategy outlines the Province's plan to promote innovation and research, establish a regulatory system and encourage the development of competitive technologies and an industrial sector. Released in 2012, the Strategy set a target of licensing 300 MW of cost-competitive in-stream tidal electricity generation.

REGULATORY FRAMEWORK

At the federal level, the Government of Canada's 2016 Budget supported the Department of Natural Resources Canada's advancement of a legislative framework for offshore renewable energy. As part of this work, Natural Resources Canada is conducting broad stakeholder engagement in 2016 and 2017, including provincial and territorial governments, industry associations, environmental organizations and indigenous organizations, to inform the development of a future legislative framework for renewable energy projects in federal offshore areas.

At the provincial level, the province 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. Now, Nova Scotia is getting ready to release *Marine Renewable Energy Regulations* in support of the Act. The Regulations will clearly establish a system for designating an area for the purpose of generating marine renewable electricity and issuing licences or permits in order to develop a marine renewable energy project. The Province anticipates that the Act and Regulations will be proclaimed in early 2017. Once proclaimed, the Act and Regulations will govern the development of marine renewable energy resources in designated areas of the Nova Scotia offshore.

MARKET INCENTIVES

The Fundy Ocean Research Centre for Energy (FORCE) is Canada's leading research centre for in-stream tidal energy, located in the Bay of Fundy, Nova Scotia. FORCE provides five berths to host technology developers, with electrical infrastructure to deliver power to the grid. Five developers with projects at FORCE have received Developmental FIT approvals from the Province, totalling 22 MW to be developed at the FORCE site:

- Minas Tidal Limited Partnership (4 MW)
- Black Rock Tidal Power (5 MW)
- Atlantis Operations Canada (4.5 MW)
- Cape Sharp Tidal Venture (4 MW)
- DP Energy (4.5 MW)

Each of these developers have received approval for the Developmental FIT path (ranging from 37.5 cents/kilowatt hour to 57.5 cents/kilowatt hour), which allows them to enter into a 15-year power purchase agreement with Nova Scotia Power, the provincial electric utility.

In addition, Fundy Tidal Inc. has received three approvals under the Province's COMFIT program, which allows local community groups to connect small scale in-stream tidal devices, under 500 kW, to the electrical grid at the distribution level over a 20-year contract at a rate of 65.2 cents/kilowatt hour.

The province of Ontario FIT Program had been introduced to develop, encourage and promote greater use of renewable energy sources including on-shore wind, waterpower, renewable biomass, biogas, landfill gas and solar photovoltaic for electricity generating projects; for electricity generating capacity greater than 10 kW and up to 500 kW projects. For waterpower, river hydrokinetic energy projects would be eligible. In 2016, the FIT Program offered a 40 years contract with energy rate of 24.6 cents/kWh.

PUBLIC FUNDING PROGRAMS

NATIONAL FUNDING PROGRAMS:

To date, Canada's main public funding program supporting national research, development and demonstrations are from federal programs administered through the Office of Energy Research and Development at Natural Resources Canada. Canada has committed approximately $37 million to marine renewable energy since 2010.

Sustainable Development Technology Canada (SDTC), an arm's length foundation created by the Government of Canada, has committed approximately $13 million to develop and demonstrate projects that include in-stream tidal, river hydrokinetic and wave energy technologies.

The National Research Council has an Industrial Research Assistance Program (IRAP) which has supported many early technology assessment and physical numerical modelling trials. Most projects have benefitted from the refundable tax credit for Scientific Research and Experimental Development.

PROVINCIAL FUNDING PROGRAMS:

At a provincial level, Nova Scotia has directly invested in the FORCE development initiative through a contribution of $11 million. In addition, the Nova Scotia Offshore Energy Research Association (OERA) has supported a number of strategic research projects in marine energy, which is estimated be a value of approximately $5.1 million. In addition, provincial economic development agencies and funds, in Nova Scotia, Quebec, Ontario and British Columbia, have provided at least $10 million to support projects.

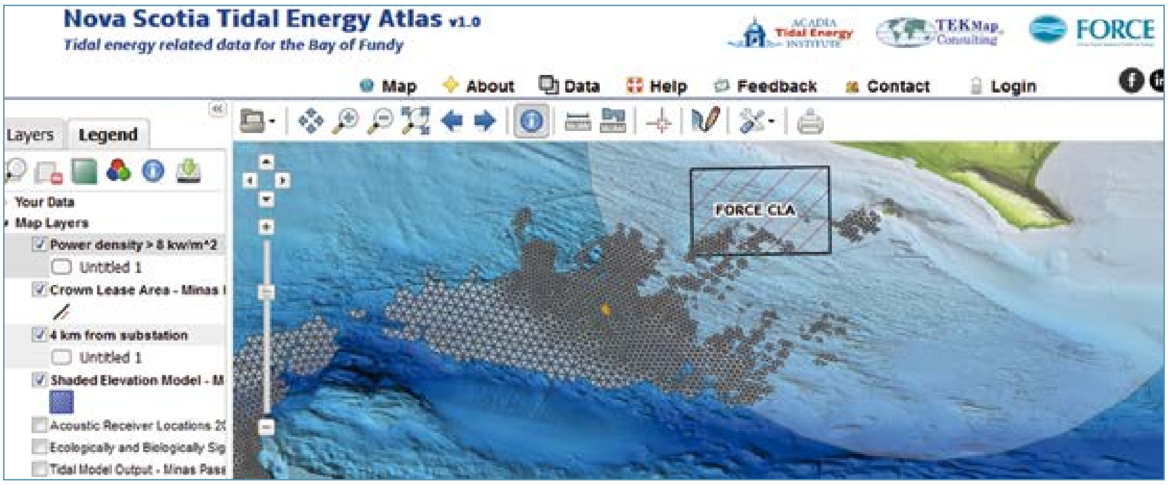
On the Pacific coast, the province of British Columbia has two programs under the Innovation Clean Energy (ICE) fund applicable to Marine Renewable Energy: The Community Energy Leadership Program, and the Post-Secondary Clean Energy Partnerships (PSCEP) Program. The ICE fund is designed to support the Province's energy, economic, environmental and greenhouse gas reduction priorities, and to advance BC's clean energy sector. In 2016, BC provided just shy of $250 thousand to support the advancement of the marine industry in British Columbia, with a focus on the development of wave energy.

RESEARCH & DEVELOPMENT

ACADIA TIDAL ENERGY INSTITUTE (ATEI)

Acadia Tidal Energy Institute (ATEI) out of Acadia University focuses on projects that seek to ensure tidal energy development is sustainable through risk reduction and informed decision making. Over the past year this work included the following:

- Completed the Nova Scotia Tidal Energy Atlas and made available for multi-stakeholder use. The atlas is an interactive web-based mapping application that makes tidal energy related spatial information readily accessible to the public (http://tidalenergyatlas.acadiau.ca/)
- Developed a hydrophone harbour porpoise click detector. Further work is underway using drifting hydrophones; this project will advance acoustic environmental sensors and software for detecting fish and marine mammals.
- Completed modelling of fish-turbine encounter probabilities using data collected from fish tracking studies
- Examination of fish presence and distributions at the FORCE site
- Development and delivery of educational programs
- Development of a Marine Renewable Energy Book in Governance,
- Studies/reports covering funding and financial supports and tidal energy resource assessment.

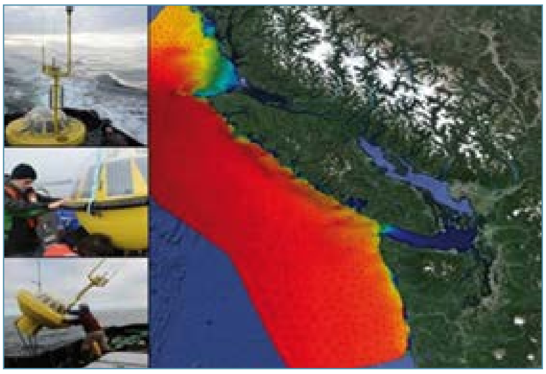


Nova Scotia Tidal Energy Atlas

WEST COAST WAVE INITIATIVE (WCWI)

The West Coast Wave Initiative (WCWI), out of University of Victoria's Institute for Integrated Energy Systems (IESVic), continues to actively contribute to cutting edge wave research and development efforts for governments, technology and project developers across the globe.

The WCWI 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. The WCWI expanded its' WEC architecture and control system modelling efforts with new collaborating technology developers in Canadian Accumulated Ocean Energy and Scottish



West Coast Wave Iniative deplying a wave buoy and SWAN model of the British Clumbia coastline

Trident Energy. This is addition to 2016 efforts for Resolute Marine Energy, Carnegie Wave Energy, Ocean Energy Ltd, and Seawood Designs.

During 2016, the WCWI worked extensively with BC Hydro (the provincial electrical utility) to provide the necessary resource and technology inputs to ensure that the provinces long-term energy system transition planning accounted for the potential development of marine energy resources in the province. Additionally, WCWI is working closely with the BC Ministry of Energy and Mines to scope out the potential for BC to play an active role in the testing, deployment and commercialization of all marine energy technologies.

WCWI researchers continue to work closely with colleagues at Sandia National Labs, the National Renewable Energy Lab and the Pacific Northwest National Lab. The relationship revolve around the development of novel wave propagation codes to allow for the implementation of WEC farms within SWAN, to plan for future wave and tidal current measurement nodes along the western seaboard of North America and best practices in wave propagation modelling and resource characterisation respectively.

OFFSHORE ENERGY RESEARCH ASSOCIATION (OERA)

Nova Scotia's support for the demonstration of in-stream tidal energy technologies has attracted companies to the Bay of Fundy from around the world. Preparations to demonstrate tidal devices at five berths at the Fundy Ocean Research Centre for Energy (FORCE) are underway in response to government legislation, investment in FORCE, feed-in tariffs, and Sustainable Development Technology Canada grants. Any risks government can reduce through financial support, infrastructure investment, and clear policy and regulations will help incubate a sustainable industry, including the economic opportunities that come from technology innovation and supply chain expertise. To help ensure Nova Scotia and Canada will benefit from a sustainable marine renewable energy industry over the longer term, research has been commissioned by the Department of Energy through the Offshore Energy Research Association (OERA) to identify a suite of applicable funding and financial support mechanisms used in different jurisdictions around the world, recommend a combination that may be suitable for the Nova Scotia context, and present the local entities that could administer such funding and financial supports for local tidal energy development. Work has also been underway on Environmental Effects Monitoring at the FORCE site that studies five major subject areas: fish, marine mammals, lobster, marine noise and seabirds. Various funding programs at OERA, such as their directed research, open calls and student research travel program, enables significant R&D to support the emerging tidal industry.

MARINE RENEWABLES CANADA – SUPPLIER DATABASE

To support industry growth and connect Canadian suppliers with marine renewable energy development opportunities, Marine Renewables Canada launched a Canadian Supplier Database in November 2016 (https://supplychain.marinerenewables.ca/). The database is designed as a tool to connect Canada's expertise with wave, tidal, and river hydrokinetic energy development needs locally, nationally, and internationally. The database will continue to be updated as further information becomes available on existing suppliers throughout Canada that could apply expertise and services to the marine renewable energy sector. Marine Renewables Canada will be focusing on continuous improvements to the database, helping to ensure increased visibility for suppliers across the country.

MAP OF CLEAN ENERGY RESOURCES AND PROJECTS IN CANADA (CERP)

CERP has been launched by Natural Resources Canada showing Canada's clean energy resources and projects by province (http://atlas.gc.ca/cerp-rpep/en/). It allows the user to easily find Canada's renewable energy resource potential for various resources, including wind, solar, river hydrokinetic, tidal, reservoir hydro and wave energy. The map allows the user to find clean energy test centres and government directed research, development and demonstration projects in emerging technologies.

BRITISH COLUMBIA MARINE ENERGY RESOURCE ATLAS AND RESOURCE ASSESSMENT

National Research Council (NRC) and Natural Resources Canada (NRCan) are collaborating to develop an interactive, publically available Marine Energy Resource Atlas. The atlas will provide information on wave, tidal and river hydrokinetic resources, combined with other relative socio-economic datasets. This atlas will be available to stakeholders as a decision support system in identifying and evaluating sites for prospective development. This project will also be used to estimate the potential future market penetration for marine renewables in the Province of British Columbia (BC). BC has been selected as a pilot location to develop the Atlas, and the resources will include tidal, wave and river hydrokinetic energy.

ADVANCING RIVER HYDROKINETIC ENERGY R&D

Natural Resources Canada (NRCan) has initiated a five year collaborative research project in advancing river hydrokinetic energy (RHE) with National Research Council (NRC), academia, and the marine energy industry. This project aims to develop new methodologies for identifying river locations for RHE projects, to evaluate and improve RHE systems performance, and to design technical guidelines for deployment of multiple turbines for large/utility scale projects.

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

Canada is fortunate to have plentiful resources available in Tidal Currents, River currents, and wave energy across the country. As such, Canada has test sites available for each of these areas outlined below:

TIDAL CURRENT TURBINE TEST SITE

The Fundy Ocean Research Centre for Energy (FORCE) is Canada's leading research centre 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. FORCE provides five berths to host technology developers with electrical infrastructure in place to deliver power to the grid. FORCE's location in the Minas Passage in the Bay of Fundy, boasts 7,000 MW of energy potential, where an estimated 2,500 MW can be safely extracted without significant effects. There is a peak surface speed of 5 m/s, and a 13 m tidal range. The five berths have been awarded and have received Feed-in Tariff approvals from the province, totalling 22 MW to be developed at FORCE.

Cape Sharp Tidal turbine (2.0 MW) being deployed at FORCE site

2016 marked a significant event for FORCE when Cape Sharp Tidal, a berth holder at FORCE, installed their first 2 MW turbine and completed a successful subsea cable connection to the provincial electrical grid in early November 2016. This turbine is now generating electricity for Nova Scotia. The second Cape Sharp turbine is scheduled to be deployed in the Spring 2017.

Black Rock Tidal Power is aiming to deploy two full scaled semi-submersible platforms, which will host an array of Schottel Hydro turbines, generating up to 2.5 MW of power per platform. Black Rock Tidal Power, a berth holder at the FORCE site, is scheduled to begin installation of their first device in 2017.

Minas Tidal Limited Partnership (Minas Tidal) is now the berth holder at the FORCE test site after Minas Energy, who previously held the berth, transferred the berth assignment to the new partnership in the summer of 2016. Minas Tidal is composed of International Marine Energy and Tocardo Tidal Power. Minas Tidal plans to deploy three Tocardo semi-submersible platforms at the FORCE site, outfitted with five 250 kW bi-directional turbine generators for a total of 1.25 MW per floating platform. Minas Tidal plans to begin the first platform deployment in 2017.

Atlantis Operations Canada and DP Energy have also received project approval from the Province and plan to deploy in-stream tidal energy technologies totalling 4.5 MW each, at the FORCE site by 2018.

RIVER HYDROKINETIC TURBINE TEST SITE

The Canadian Hydrokinetic Turbine Test Centre (CHTTC) in Manitoba, is operating using dedicated infrastructure on the Winnipeg River to test river hydrokinetic energy technologies. This facility is managed by team from University of Manitoba. The site is available to all Canadian and international companies developing hydrokinetic technologies focused on advancing and de-risking their technology. In 2016, CHTTC worked with Mavi Innovations, New Energy, and Gem Holdings to test their turbines on the Winnipeg River.

A flow measurement campaign was undertaken to characterize the velocity and turbulence profiles at the CHTTC. This will help to enhance the growth of river hydrokinetic energy industry technologies. The procedures developed at the CHTTC were applied to simultaneously operate a vertical ADCP, a horizontal ADCP and position an ADV within the water column.

To further advance river hydrokinetic technologies and to address Canadian Labour Code requirements, the CHTTC documented its river hydrokinetic turbine procedures. The CHTTC is working towards having the expertise within a commercial setting to apply the International Electrotechnical Committee's TC-114 standards (for Marine and river hydrokinetic energy) and provide manufacturers certification of their hydrokinetic turbines.

WAVE ENERGY CONVERTER TEST SITE

The College of the North Atlantic (CNA) operates the Wave Energy 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. CNA has also installed and commissioned instrumentation to characterize the weather and wave conditions at the site, and completed bathymetric mapping of the area. 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. With a dedicated wharf and slipway, the site is ideal for the testing and demonstration of wave energy converters and other surface and sub-surface structures in an energetic near-shore environment as well as the development of associated instrumentation and sensor systems.

The CNA has completed scaled model testing and expects to deploy a full scale prototype in 2017. This 10 ton wave energy converter is designed as a robust, low technology point absorber conceived to deliver a high volume of water to shore. The water can be used in industrial, aquacultural and electrical generation applications.

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 Venture installed the first of their two turbines into the Bay of Fundy at the FORCE site in Nova Scotia. The 2.0 MW turbine was installed and connected to the Nova Scotia electricity grid in November 2016.

Mermaid Power Corporation deployed its Neptune 3 wave energy device at Keats Island in December 2015 and was followed by Neptune 3A deployment in early September 2016.

Idénergie installed 6 river hydrokinetic turbines in 2016 to national parks in British Columbia and National parks. The turbines were installed for seasonal purposes and were removed for the winter. In 2017, additional 5 river hydrokinetic turbines will be installed in various Parks Canada site across Canada at approximately 0.5 kW nameplate capacity.

Idénergie turbine ready for deployment

Water Wall Turbine deployed 500 kW full size in-stream tidal demonstration turbine at Dent Island, BC in June 2016. Microgrid optimization utilized integrating the diesel gensets, turbine, and a Tesla energy storage system. The unit has been removed from the site with plans to redeploy in 2017.

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

Water Wall Turbine deployed at Dent Island, British Columbia

PLANNED DEPLOYMENTS

In the Bay of Fundy, there are another 20 MW of in-stream tidal energy planned deployments at the FORCE site. There are five technology developers planning deployments between 2017 and 2018: **Cape Sharp Tidal Venture**, 2.0 MW turbine in 2017; **Black Rock Tidal Power,** up to 5.0 MW with deployments beginning in 2017; **Minas Tidal Limited Partnership**, up to 4.0 MW with deployment beginning in late 2017; **Atlantis Operations Canada**, up to 4.5 MW with deployments beginning in 2018; and DP Marine Energy, up to 4.5 MW with deployments beginning in 2018.

New Energy Corp. has been working with a First Nations community in Manitoba to supply a 25 kW EnviroGen Power Generation System. Approval and permits are in place, installation of the system is scheduled for summer of 2017. In partnership with CHTTC and Natural Resources Canada/CanmetENERGY, this project will be fully equipped to monitor the turbine performance.

In 2017, **Mavi Innovations** will be deploying the Mi1 floating tidal turbine at Blind Channel Resort and Marina to offset the operator's use of diesel fuel. The turbine will be integrated into the existing diesel network, along with an additional smart diesel gen-set and battery storage. Engineering, procurement and assembly were completed in 2016 with installation scheduled for spring 2017. Mavi will work with project partners including the University of Manitoba to measure the performance and assess the feasibility of this hybrid tidal power system.

As a result of the successful deployments at Keats Island, **Mermaid Power Corporation** has been able to make modifications for a new device, Neptune 4, which is under design and is targeted for deployment in early summer 2017.

Yourbrook Energy Systems launched a 3-month pilot project in Haida Gwaii for a small-scale prototype of its systems (up to 80 kW) in the Juskatla Narrows of Masset Inlet. The main objective of the project is to decrease the use of diesel generation in the region by replacing it with clean energy from tidal power.

In April 2016, **Big Moon Power** successfully completed their test trial of their Kinetic Keel technology in the upper Bay of Fundy. Big Moon Power considers their technology to be scalable and a viable system for generating electricity from the ocean's tides. They are planning their next steps as they continue to study their technology and its ability to function in the Bay of Fundy environment.

Many Canadian technology developers have been working with international partners to export their technology for future deployments in other countries.

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 sub-committee, 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. The net result of these efforts includes the publication of 8 technical specifications, with many others currently being drafted.

NEW INTERNATIONAL COLLABORATIONS

In November 2016, the Offshore Energy Research Association of Nova Scotia (OERA) and France Energies Marines (FEM) signed a memorandum of understanding to encourage joint research to develop new and innovative cost-reduction technologies and environmental effects monitoring for high-flow tidal environments. As a result of this MOU, a joint research call will be launched in 2017.

INTER-PROVINCIAL INITIATIVES

The province of Nova Scotia and the province of British Columbia have a signed memorandum of understanding on marine renewable energy – to further develop a cooperative approach to its respective marine energy development goals, which includes working with Nova Scotia's OERA.

BRITISH COLUMBIA'S INDUSTRIAL MARINE PROJECT

The province of BC is investing $200,000 in a partnership with the Association of British Columbia Marine Industries' (ABCMI) that will expand economic opportunities for the industrial marine sector. The goals of the "BC Industrial Marine Project" are to develop a baseline assessment and estimate of the marine sector's economic impact, identify opportunities for marine sector growth for the near and long term, and serve as a platform to support increased productivity and competiveness for future industrial marine activities. ABCMI has a mandate to bring together key stakeholders and work as a coordinated, representative voice to strengthen the BC industrial marine sector and champion its growth. The project will support a better understanding of the scope, capabilities, capacity, and characteristics of its broad industrial marine membership base including shipbuilding, refit, and ship repair; small craft marine; marine products; ocean science and technology (including marine renewable energy); marine industrial services; and marine professional services.

BRITISH COLUMBIA'S ROAD MAPPING EXERCISE

The BC Ministry of Energy & Mines is exploring a marine renewable energy initiative to support future development of innovative energy generating technologies. A road mapping exercise supported by the ICE Fund is underway to inform the full scope of stakeholders and to ensure the required consultations on this opportunity. A consultant is currently interviewing individuals across relevant areas of the public sector and stakeholder communities to develop a better understanding of the opportunity. This initiative has many touch points for stakeholders including: Environmental considerations; Energy and utilities; Economic development; Technology and innovation; and International access. The Road Mapping is expected to be completed in early 2017.

CENTRE FOR OCEAN VENTURES AND ENTREPRENEURSHIP

COVE is a collaborative facility based in Halifax Harbour, Nova Scotia for applied innovation in the ocean sector. Their mission it to propel the ocean economy by providing high quality marine infrastructure and a collaborative space in which a community of ocean enterprises can start, grow and prosper. Their primary goal is support ocean technology commercialization. The collaborative space at COVE will be home to local and global ocean technology businesses, start-ups, researchers, marine-based and service businesses that support the ocean technology sector.

CONFERENCES

The Marine Renewables Canada Annual Conference will be held in the fall 2017, Ottawa, Ontario.

CHINA

XIA DENGWEN *National Ocean Technology Centre*

INTRODUCTORY NOTE

In 2016, the Chinese Government released the "Outline of the 13th Five-Year Plan for Economic and Social Development", emphasizing the development of the blue economy, protecting the marine environment and responding to global climate change. The "Action Plan for Energy Technology Revolution and Innovation (2016-2030)", released by the National Development and Reform Commission (NDRC), in March 2016, aims to develop marine renewable energy demonstration projects and to establish a supply chain for marine renewable energy by 2030.
The State Oceanic Administration (SOA) will release the "13th Five-Year Plan (2016-2020) for Marine Renewable Energy", expecting to cover 6-8 island projects for multi-energy complementary power supply based on marine renewable energy with a target of 50 MW by 2020.The SOA and the Ministry of Finance (MOF) of China are continuing to fund marine renewable energies; a budget of RMB 100 million has been granted in 2016.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The Chinese Government released the "Outline of the 13th Five-Year Plan for Economic and Social Development", in March 2016, providing a framework for economic and social development of China. The plan highlights the potential opportunities for the energy mix, and the active exploitation of tidal power in coastal areas.
The "Action Plan for Energy Technology Revolution and Innovation (2016-2030)" was released by the National Development and Reform Commission (NDRC) and the National Energy Administration (NEA) in March 2016. The plan sets goals to develop high efficiency power generation devices in marine renewable energy (MRE), implement MW MRE energy demonstration projects, and establish a complete industry chain of MRE by 2030.
In December 2016, the "13th Five-Year Plan for Renewable Energy" was released by NEA. The plan emphasizes the importance of promoting the demonstration and application of MRE, accelerating the construction of national ocean energy test sites and solving the bottlenecks influencing the energy conversion efficiency of ocean energy.
The State Oceanic Administration (SOA) is developing the "13th Five-Year Plan (2016-2020) for Marine Renewable Energy Development". The plan sets goals to construct three marine renewable energy industrial parks, implement 6-8 island multi-energy complementary projects based on marine renewable energy, reach demonstration projects into 50 MW in total by 2020.

REGULATORY FRAMEWORK

In December 2016, the Amendment to the "Interim Measure for the Special Funding Programme for Marine Renewable Energy" was released by SOA. It adjusted the focus of SFPMRE, including demonstration of key technologies and industrialization, large scale development, public platform construction, and integration of marine renewable energy.

MARKET INCENTIVES

In February 2016, the "Guidance on Promoting the Development of the 'Internet +' Smart Power" was released by NEA, emphasizing to build the Intelligent system of energy consumption and improve the proportion of RE as well distributed energy in the electricity supply.

PUBLIC FUNDING PROGRAMMES

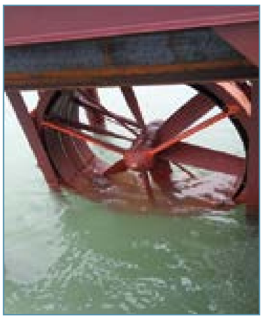
In 2016, RMB 100 million budgets were granted by SFPMRE (Special Funding Plan for Marine Renewable Energy) to support 6 projects, including the tidal current energy demonstration, buoy system based on wave energy, power system of instruments based on tidal current energy, power system of offshore cage based on wave energy, assessment system of MRE technology, data system of MRE resource. To date, China has committed approximately RMB 1 billion to marine renewable energy RD&D since 2010.

RESEARCH & DEVELOPMENT

TIDAL CURRENT ENERGY

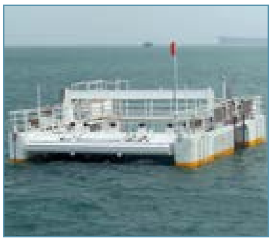
Northeast Normal University (NNU): **NNU turbine** (15 kW) is a H-axis turbine, with cut-in speed of 0.45 m/s. The NNU turbine has been deployed near Zhaitang Island for open sea test since May 2016. The maximum output power is 15 kW, and the conversion efficiency is 25%. In 2016, CSSC Electronics Technology Co. Ltd and NNU were funded RMB 10 million by SFPMRE to develop the power system for ocean observation equipment based on NNU turbine.

Institute of Electrical Engineering (IEE) of the Chinese Academy of Sciences (CAS): IEE turbine (2×2.5 kW) is a floating H-axis turbine installed on the platform. The platform is 36m × 8m × 2m. The device was deployed near Xisan Island for open sea test in July 2016. During the test, the maximum output power is 1.73 kW, and the conversion efficiency is 40%.



WAVE ENERGY

Guangzhou Institute of Energy Conversion (GIEC) of the Chinese Academy of Sciences (CAS): In November 2015, the 100 kW prototype of Sharp Eagle Wanshan was deployed for testing in Wanshan Islands. The device is 36m × 24m × 16m. Different from the single floating buoy of Sharp Eagle I, the 100 kW Sharp Eagle is installed with four floating buoys, which are placed with two buoys on each side symmetrically. As verified by the test result, the wavelet is available to be absorbed and the good performance on wave energy absorption is proven. During testing time, when the wave period between 4~6.5 seconds and the wave height range of 0.6~1.8 meters, most of the data remain above 20%, with the highest efficiency reaching 37.7%. The amount of electricity generated accumulated more than 30 MWh till June 2016.



Share Eagle I (10 kW)

Share Eagle II (50 kW)

Share Eagle Wanshan

Share Eagle Wanshan

The Institute of Electrical Engineering (IEE) of the Chinese Academy of Sciences (CAS): Supported by the SFPMRE, the IEE invented a novel point-absorber wave energy converter (10 kW) based on magnetohydrodynamic generators. The device was deployed for open sea testing near the Wanshan Islands. The total efficiency of the device is about 17.8%. The project passed the SOA inspection in July 2016.

OTEC

Supported by SFPMRE, the First Institute of Oceanography (FIO) of the SOA is developing an OTEC device using non-azeotropic ammonia-water mixture since 2013. The FIO has completed the design and installation of the OTEC system in 2016. The device achieves the power of 10 kW with its total efficiency over 3%. The FIO will carry out testing operation to verify the reliability of the OTEC system in 2017.

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

The national small scale test site in Weihai, Shandong Province, achieved two successful operations in 2016: Completed the preparation for subsea cable system development at the test site, which is an interconnection hub that will connect the test platform to the test centre, and committed to start the operation of the monitoring centre.

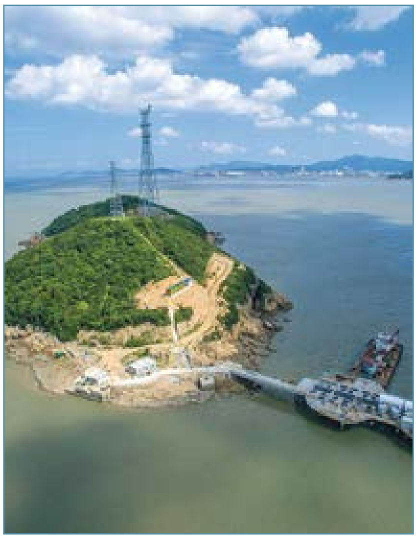
Concerning the national tidal energy full scale test site in Zhoushan, Zhejiang Province, the feasibility study had passed the inspection of the SOA to initiate the comprehensive demonstration project.

Concerning the national wave energy full scale test site in Wanshan, Guangdong Province, the 1100 m2 land area has been authorized for use in November 2016, and the permit application of sea areas is still in progress.

OPERATIONAL PROJECTS

Jiangxia Tidal Power Plant: Built in 1980 and owned by China Longyuan Power Group Co. affiliated to China Guodian Corporation since 2003. Sponsored by the SFPMRE, the upgrading project (#1 turbine from 500 kW to 700 kW) passed the SOA inspection in July 2016. The new turbine has been operating for more than 2400 hours with power generation of 967 MWh.

LHD Tidal Current Energy Demonstration Project: Supported by the SFPMRE, Zhejiang Major Science Technology Project (ZMSTP), Hangzhou United Energy Co. Ltd. is developing the LHD Tidal current energy demonstration project. They plan to install 7 turbines in their platform, with installed capacity of 3400 kW. The platform was deployed near the Xiushan Island in March 2016. In August, Hangzhou United Energy Co. Ltd. installed two of their turbines in the platform (#1 turbine: 400 kW, #2 turbine: 600 kW), and connected them to the grid. To date, the power generation has accumulated to more than 170 MWh. In 2016, Hangzhou United Energy Co. Ltd. was funded RMB 45 million by the SFPMRE to press ahead with the next phase project.



Zhairuoshan Tidal Energy Power Demonstration Station: In 2015, the Zhejiang University (ZJU) installed a 120 kW turbine near the Zhairuoshan Island (with their 60 kW turbine already deployed in 2014). To date, the total power generation has accumulated to more than 30 MWh. In the future, the station can serve as a testing platform for tidal current energy turbines. Supported by the SFPMRE, the year 2017 will see the assembly and deployment of a new 50 kW hydraulic type turbine developed by the ZJU, as well as a 300 kW turbine developed by Guodian United Power Technology Co. Ltd..

Shengshan Island Isolated Hybrid Power Demonstration Station: Developed by Shanghai Marine Diesel Engine Research Institute (SMDERI), the station comprises 300 kW WEC, 150 kW wind turbines, 50 kW bio-energy devices and 25 kW solar thermal cells. The station passed the SOA inspection in July 2016. The SMDERI plans to build an Ocean Energy Comprehensive Utilization Demonstration Centre based on the demonstration station.

PLANNED DEPLOYMENTS

Shandong Rongyuan New Energy Co. (SRNE): The SRNE is developing a 110 kW floating point-absorber WEC based on the WEC developed by the Shandong University (SDU). The SRNE has completed the commissioning test for the WEC, and will deploy the device near the Chu Island in February 2017.

China Shipbuilding Industry Corporation 710 Institute (CSIC710): CSIC710 has repaired the 100 kW floating raft WEC, which was damaged by a typhoon in 2015. CSIC710 optimized and improved the mechanical-linkage system, and will deploy the 100 kW WEC near the Wanshan Island in June 2017.

OTHER RELEVANT NATIONAL ACTIVITIES

The 5th China Marine Renewable Energy Conference (CMREC), hosted by the NOTC and the Administrative Centre for Marine Renewable Energy (ACMRE), was held on 6th May 2016 in Zhoushan, Zhejiang Province. The theme was “improving the readiness level, and advancing the application level”. More than 200 government bodies, universities, institutes, businesses and stakeholders participated in the conference.

DENMARK

KIM NIELSEN *Ramboll*

INTRODUCTORY NOTE

In the start of 2016, WaveStar declined the opportunity to pursue a H2020 grant for building a 500 kW prototype in Belgium. During 2016, WaveStar has reduced its activities and the iconic WaveStar from the Port of Hanstholm has been recycled. Floating Power Plant entered partnership with DP Energy in Ireland with the focus to develop wave energy sites in south Wales and north Scotland respectively.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The "Danish Partnership for Wave Energy" is a network stimulating innovation and collaboration on wave energy development in Denmark. The Danish Wave Energy developers met under this umbrella, in May and November 2016, to discuss and disseminate results from ongoing projects, either national or international. The Partnership is a result of the National strategy on wave energy proposed in 2012 and responsible for the Roadmaps for Wave Energy Development in 2015.

REGULATORY FRAMEWORK

The Danish policies on climate change mitigation is driven partly by compliance with international climate obligations, and partly by achieving national targets in the energy sector, which is a major source of greenhouse gas emissions from Denmark. The regulatory framework for the Danish climate related policies is laid out in the Danish climate law. The law includes the following main messages:

1. A council on climate change, independent and academically based, is to be established.
2. An energy policy report is to be submitted by the Government to the Parliament every year.
3. New national climate targets are to be established each year.

The Danish Council on Climate Change was established in 2015, and consists of distinguished academic experts in the fields of energy, transportation, agriculture, environmental protection, nature and economics. They are to publish their recommendations to the Government on the climate effort. Further, the experts are to contribute to the public discussion on the Danish climate efforts. The council is appointed for four year terms, and consists of a chairman and six experts.
Read more on the work and recommendations of the Council on Climate Change (http://www.klimaradet.dk/en/frontpage).

The Minister of Energy, Utilities and Climate is obliged by the law to submit an annual energy policy report to the parliament. The report presents a status of current greenhouse gas emissions and Denmark's outlook on compliance with international obligations.
Finally, the climate law obligates the Minister of Energy, Utilities and Climate to propose national climate targets at least every fifth year. The targets must have 10-year perspectives and the level of ambition needs to point towards the ambitions for Denmark to be independent of fossil fuels by 2050.

MARKET INCENTIVES

In Denmark, the incentives for Wave Power Developments are similar to Wind Energy. The Danish Partnership for Wave Energy has proposed methods to improve the Incentives for stimulating Wave Energy Development in Denmark. The incentives in other countries are explored by Floating Power Plant (FPP) which combines wave and wind on a single floating platform. FPP is moving on in partnership with DP Energy in Ireland, creating two new project companies, Dyfed and Katanes Floating Energy Ltd, developing sites in south Wales and north Scotland respectively. In 2015 Floating Power Plant Ltd, established offices in Scotland, to contribute to these developments, as well as building links to the local supply chain. Floating Power Plant P80 technology platform combines a 5-8 MW floating wind turbine with a 2-3,6 MW wave device.

PUBLIC FUNDING PROGRAMMES

The main source for public funding for Wave Energy is the energy technological development and demonstration programme (EUDP). The purpose of EUDP is to exploit and develop the Danish business potential within the energy sector, as well as reaching a number of political goals including supply security, a cleaner environment, and cost efficiency. EUDP can provide grants for development and/or demonstration of all energy technologies contributing to reaching political goals for energy in the following areas:

- Biomass technology and systems for transportation and energy
- Wind and **other renewable energy technologies** (this is where Wave Energy is placed);
- Hydrogen and fuel cell technologies;
- Low energy buildings;
- Energy efficient solutions, including end-consumption and flexible energy consumption;
- Integrated energy systems (integration of technologies), including transportation of energy;
- More effective recovery of oil and gas;
- More effective and environmentally friendly production overall (electricity and gas), including CO_2 storage.

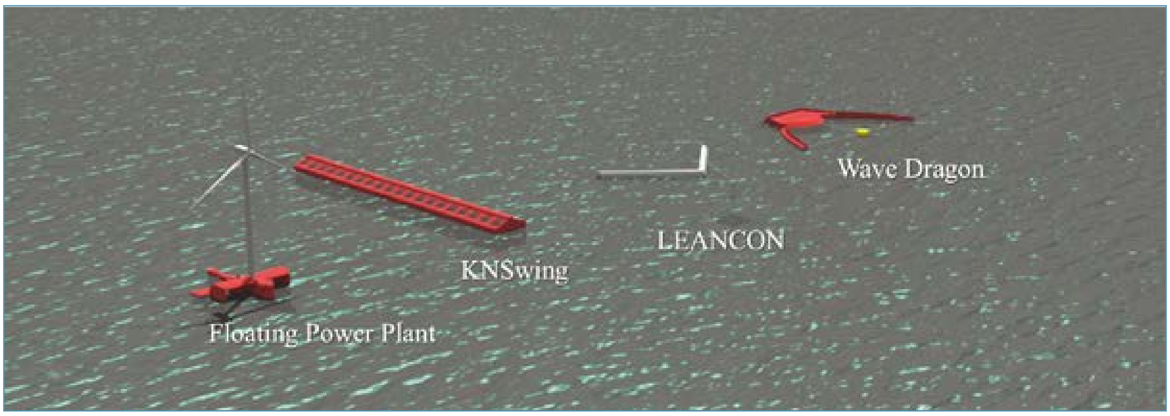
EUDP has a yearly budget of approximately DKK 180 million for co-financing the development and demonstration of new and effective energy technologies. With a successful application of the programme, companies will receive:

- DKK 2.5-50 million for development and demonstration;
- A network of partners for development and commercialisation;
- Technology and knowledge transfer.

RESEARCH & DEVELOPMENT

The Wave Energy Research Group (WERG) at Aalborg University is coordinating two EUDP supported research projects:

1. "Mooring Solutions for Large Wave Energy Converters" - is a R&D project to research common mooring solutions for large wave energy converters. It is a 3-year project funded by EUDP with €1 million initiated in 2015 and coordinated by Aalborg University. The objective is to design, test and develop cost efficient mooring solutions for large, slack moored, floating wave energy converters and to build national competences in design and modelling of mooring systems for WECs. Project partners are Tension Technology International, Chalmers University of Technology, and four wave energy developers, Floating Power Plant, Leancon, Wave Dragon and KNSwing.



Large WECs used as test cases in the development of mooring systems

2. "Resource Assessment, Forecasts and WECs O&M strategies at DanWEC and beyond" - coordinated by Aalborg University, is a 3-year project initiated in 2015 and supported by the EUDP. The objective of the project is i) to define the long-term wave climate around Hanstholm area using measurements from three buoys off Hanstholm and by validating modelled against buoy-measured data; ii) to build competences in defining Operation and Maintenance strategies for wave energy converters (WECs) and other offshore activities in the study area.

At WERG, the final preparations of a new state-of-the-art wave laboratory are being made. The fully equipped laboratory will be capable of generating 3-D waves and currents, using 3-D active wave absorption in the wave basin and 2-D waves and currents in the flumes with 2-D active wave absorption.


The new building of the Department of Civil Engineering (left) and the new wave laboratory under preparation (right)

Wave Dragon participated in two EC supported projects, which were finalised in 2016: The "ACORN" project, where solutions to combined corrosion and marine biofouling were developed, http://www.acorn-project.eu/ - and "Maribe", where Wave Dragon developed a combined wave energy and seaweed production plant aimed at deployment in the Irish Sea https://maribe.eu/

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

DanWEC Hanstholm is the Danish test site for wave energy – suited for testing prototypes. The test site is exposed to the waves from west with a fetch of about 600 km. The water depth in the dedicated area of 2 by 4 km is between 10 and 35 meter and distance to port 4 km.
The wave resource is about 6 kW/m and the maximum significant wave height about 9 m, these conditions are currently being monitored and updated.

DanWEC Hansholm testsite

Nissum Bredning is a sheltered test site with a fetch of about 5 km to the west and 9 km in the direction SW. The water depth is between 1 and 5 m, the resource is less than 1 kW/m and the maximum significant wave height about 1-2 m. This test site is well suited for 1:5-10 scale experiments.

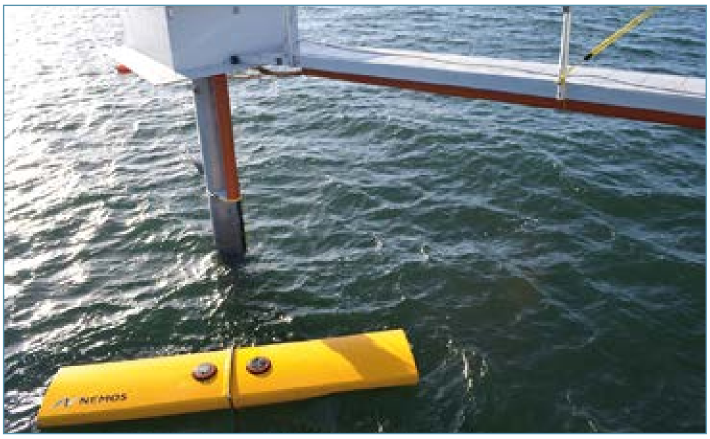
Nissum Bredning Test site

OPERATIONAL PROJECTS

Wavepiston was re-Installed at DanWEC test site in Hanstholm during the summer of 2016.

Wavepiston (2016)

The German wave energy system **NEMOS** is being tested at the sheltered DanWEC site in Nissum Bredning.



Nemos at Nissum Bredning in operation (2016)

PLANNED DEPLOYMENTS

Resen Waves are in the preparation stage for new rounds of sea testing in Nissum Bredning. Initial testing was completed in 2016 as shown on the picture.

Resen Wave initial test of new design in 2016

Weptos plans the installation and testing of a prototype north of Brandsø, in Lillebælt, for a period of two years starting 2017.

Weptos preparing for deployment in 2017

CrestWing plan to install in Kattegat, during 2017. The inventor and developer of Crestwing, Henning Pilgaard, passed away in 2016. Henning Pilgaard was a driving force within wave energy development in Denmark.

EUROPEAN COMMISSION

DAVIDE MAGAGNA *DG JRC* MATTHIJS SOEDE *DG RTD*

INTRODUCTORY NOTE

In 2016 the European Commission has strengthened its support for the development of ocean energy technologies. Ocean energy is expected to contribute to decarbonisation of the EU energy system by providing up to 10% of the European electricity needs by 2050 [Ocean Energy Forum 2016], and to help maintaining Europe's leading role in the development of renewable energy technologies.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The development of ocean energy at European level has been addressed by a number of recent policy initiatives, following the launch of the Ocean Energy communication in 2014 (COM/2014/08) and the subsequent establishment of the Ocean Energy Forum. Currently, the main policy drivers for the development of ocean energy technologies are the Energy Union Package and the implementation of the Strategic Energy Technology Plan (SET-Plan).

FEB 2014	DEC 2014	FEB 2015	SEPT 2015	SEPT 2016	NOV 2016
Ocean Energy Communication (COM/2014/08) Setup Ocean Energy Forum Roadmap expected end of 2016	Towards an Integrated Roadmap: Research Innovation Challegendes and Needs of the EU energy System 13 Actions in 3 different programmes for the uptake of Ocean Energy in EU	Energy Union (COM/2015/80) Retain Europe's leading role in global investment in renewable energy EU	Energy Union (COM/2015/6317) Reduce the cost of key technologies Increase regional cooperation in the Atlantic area for ocean energy	SET-Plan Declaration of intent, defining LCOE targets for tidal and wave energy	Publication of the Ocean Energy Strategic roadmap developed by the Ocean Energy Forum and supported by DG Mare

EU policy initiatives directed to the development of ocean energy technology

The Energy Union package (COM/2015/80) sets out the five overarching dimensions for an integrated and sustainable European energy system. The integrated SET-Plan (COM/2015/6317) supports the Energy Union package with the provision of a new approach to Research & Innovation (R&I), designed to accelerate the transformation of the European energy system through the development and deployment of low-carbon energy technologies. 10 actions for the transformation of the European energy system are included in the SET-Plan, and the development of ocean energy is expected to contribute to the followings:

1. Sustaining technological leadership by developing highly performant renewable technologies and their integration in the EU's energy system;
2. Reducing the cost of key technologies.

Following a two-year period of discussion, in September 2016, the European Commission and stakeholders have agreed to ambitious targets for the development of ocean energy in Europe. The targets, presented in the "SET Plan – Declaration of Intent on Strategic Targets in the context of an Initiative for Global Leadership in Ocean Energy" [European Commission 2016], aim to ensure that Europe maintains its leadership in the sector and to identify in a coordinated manner avenues to achieve these targets (Table 1).

TECHNOLOGY	YEAR	TARGET
TIDAL	2025	15 cEUR/kWh
TIDAL	2030	10 cEUR/kW
WAVE	2025	20 cEUR/kW
WAVE	2030	15 cEUR/kW
WAVE	2035	10 cEUR/kW

Table 1 LCOE Targets for Wave and Tidal technology presented in the SET-Plan declaration of intent.

The current policy framework at EU is trying to provide technology developers with the required stability and commitment to bring ocean energy technology to the market.

The implementation of the SET-Plan foresees the creation of a working group on Ocean Energy to identify viable actions for the development of the technology in line with the targets set. The newly formed European Technology and Innovation Platform on Ocean Energy (ETIP Ocean) is in fact doing this. It developed a more detailed Strategic Research Agenda for Ocean Energy [ETIPOcean 2016], will continue the dialogue in between all stakeholders, and will take up the implementation of the SET Plan actions. The scope of the ETIP covers the whole innovation chain as well as bringing technologies to the market by for instance identifying innovation bottlenecks.

Further scope for the development of ocean energy is provided by the Smart Specialisation Platform on Energy (S3PEnergy; http://s3platform.jrc.ec.europa.eu/s3p-energy). The S3PEnergy initiative is designed to harmonise the regional effort in the development of ocean energy. It facilitates collaboration by matching research and innovation strengths with business needs; with the aim to identified address emerging opportunities and market developments in a coherent manner. A regional partnership for regional collaboration on ocean energy was established in 2016 under the S3P umbrella, with a number of key European regions already participating in the initiative.

The development of Ocean Energy is supported by the European Commission through different mechanisms, ranging from R&D projects and market incentives.

MARKET INCENTIVES

To support the development of innovative low-carbon technologies the European Commission has created a number of instruments aimed at reducing the gap between R&D and commercialisation. The NER300 programme is designed to support first-of-a-kind, commercial-scale renewable energy projects. Five Ocean Energy projects have been awarded from NER300: two tidal projects to take place in the UK (Scotland), two wave energy projects based in Ireland and Portugal and one OTEC project to be installed in Martinique. Details are as presented in Table 2.

COUNTRY	TECHNOLOGY	PROJECT	NER300 AWARD (MILLION €)	PROJECT STATUS
UK	Tidal	Sound of Islay	20.65	Planned
UK	Tidal	Stroma/MeyGen phase 1B (Kyle Rhea)	16.77	Planned (Formerly awarded to Marine Current turbines and now acquired by Atlantis Resources LTD for phase 1B of the MeyGen Array)
FR	OTEC	Nemo	72	Planned – To be installed in Martinique
PT	Wave	Swell	9.1	Planned
IE	Wave	WestWave	23.2	Planned

Table 2 Pre-commercial projects awarded support through NER300

PUBLIC FUNDING PROGRAMS

Further incentives are provided by the EU in the form of loans for first-of-a kind projects, through the pilot InnovFin Energy Demo Projects (EDP) scheme in collaboration with the European Investment Bank (Table 3). The scheme was design to reduce the risk for demonstration projects, for which the supply of the supply of equity and debt is at much lower levels than the financing of proven low carbon technologies. The InnoFin EDP scheme is a new public sector funding mechanism designed to fill the commercialisation, 'Valley of Death', funding gap.

COUNTRY	PROJECT	FUNDING (MILLION €)	DATE
PT / FI	WaveRoller	10 (3PT & 7 FI)	06/07/2016

Table 3 Projects supported by EIB InnovFin Energy Demo

RESEARCH & DEVELOPMENT

The Horizon 2020 is the current framework programme put in place by the European Commission to support innovative R&D actions. Since its inception in 2014, the H2020 programme has provided more than 66 million Euros for ocean energy R&D to twenty different projects.

In 2016 alone, nine projects have received funding from the EU H2020 programme for 18.5 million EUR. Of the nine projects, six address research and innovation for the development of wave and tidal energy technologies. An overview of the H2020 projects awarded in 2016 is presented in Table 4. The focus of H2020 funded projects is to identify viable ways for the reduction of the cost associated with ocean energy, through technological improvement. A specific area of interest is the power take-off, for both tidal and wave energy technologies, which is addressed in eight-funded H2020 projects.

TITLE	ACRONYM	TECHNOLOGY DEVELOPER	PROJECT STATUS
Demonstration of Integrated Solution for offshore Tocardo Tidal power plants.	InToTidal	Tocardo	Demonstration of deployment solutions for tidal turbines
Technology Advancement of Ocean energy devices through Innovative Development of Electrical systems to increase performance and reliability	TAOIDE	Ocean Renewable Power Company	Development of wet-gap generators, Life time cost reduction. Achieve availability of 96%
Tidal Turbine Power Take-Off Accelerator	TIPA	Nova Innovation	PTO optimisation and cost reduction of 20% of lifetime costs.
Advanced Braking Module with Cyclic Energy Recovery System (CERS) for enhanced reliability and performance of Wave Energy Converters	WaveBoost	Corpower	The project aims at improving the PTO for the next generation Corpower device. The first Corpower WEC is to be tested in EMEC next year (TRL6), while the project focus on developing further a new PTO (TRL5) to reduce of 30% LCEO to be mounted in future Corpower technology.
European Technology and Innovation Platform for Ocean Energy	ETIP OCEAN	N/A	ETIP Ocean is tasked with the provision 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.
Multi-Use in European Seas	MUSES	N/A	The MUSES project aims to review existing planning and consenting processes against international quality standards for maritime spatial planning (MSP) and compliance with EU Directives used to facilitate marine and coastal development (including ocean energy) in EU waters.
DEMOnstration for Tidal Industry DErisking	DEMOTIDE	DEME Blue energy/Atlantis	The Demotide project aims 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.

Table 4 Ocean Energy R&D H2020 projects awarded in 2016

Unfortunately the Horizon2020 project Upwave coordinated by Wavestar had to terminate their demonstration project in 2016.

Additional support for the development of ocean energy is provided by the European Commission Interreg Programme, which is designed to fosters transnational cooperation. In this context, the Foresea (Funding Ocean Renewable Energy through Strategic European Action) project was launched. The project aims to help bring ocean energy technologies to market by providing access to some of Europe's world-leading network of test centres: EMEC (UK), SmartBay (Ireland), SEM-REV (France) and the Tidal Testing Centre (Netherlands). 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. In 2016, the Foresea project has launched two calls for funding to support ocean energy demonstrations in one of the four test centres, and made recommendations to support 10 developers as a result of the first call.

Further support to R&D activities is provided through the OceanERA-NET, an initiative that coordinates national research activities of member States in the European Union and associated states in the field of Ocean Energy. The existing OceanERA-NET has supported transnational collaborative demonstration projects.

OTHER RELEVANT NATIONAL ACTIVITIES

In 2016, within framework contract for "Studies in Support to Research and Innovation Policy in the areas of Renewable Energy, Carbon Capture and Storage and Clean Coal" DG Research and Innovation has launched a study on "Lessons for Ocean Energy Development". The study focuses on tidal and wave energy and analyses failures and good practices/ lessons learnt in past developments, covering technological and non-technological issues and barriers for cooperation (finance, IPR, business operation). The results of the studies are expected to be presented in early 2017, and to provide recommendations for the development of the Ocean Energy sector in the coming years.

FRANCE

YANN-HERVÉ DE ROECK *France Energies Marine*

INTRODUCTORY NOTE

Following a trend over several years, the French Marine Renewable Energy (MRE) sector activities in 2016 can be characterized by a large and complimentary set of public and private initiatives and achievements. The size of projects and their objectives vary considerably. As an example, tidal turbines are being tested in order to be combined in arrays as part of the global network energy mix, but also individually to provide energy to non-grid connected islands or isolated communities, as well as along rivers and in estuaries.
Motivated by the potential of its oversea islands in the intertropical area, France is also heavily investing in OTEC. While on the fringe of the OES perimeter of action, but contributing to its progress by tackling many of the MRE common issues, the floating offshore wind turbine sector is also moving forward quickly with strong public and industrial involvement, setting a consistent roadmap for development.
As a result of these shared interests, up to 3000 people meet and collaborate at national exhibitions and conferences dedicated to the global Marine Renewable Energy sector.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

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 of this Energy Act, on October 27th 2016, the multi-annual Energy Programme (Programmation pluriannuelle de l'énergie) defined specific objectives in terms of installed capacity of the various energy sectors for electricity production. A complementary objective is set between 200 and 2000 MW as an additional capacity to be awarded for marine energy (again, ocean energy and floating offshore wind) based on the feedback and cost improvements from the pilot farms demonstrations. In line with these targets, two calls for tenders for commercial arrays have been announced to be open by the 1st semester of 2017, for tidal current and floating wind respectively.
In order to calculate the total installed capacity by 2023, the given figures must also include the operational tidal range barrage of 240 MW of the Rance river running since 1966, as well as one 10.6 MW OTEC plant scheduled to be operational before this date.
In parallel, France has accelerated its Marine Spatial Planning (MSP) by launching a consultation in 2016, and pursues identification of dedicated sites for ocean energy projects.

REGULATORY FRAMEWORK

A simplification of the consenting process was initiated by the French Government in 2014 in order to accelerate the development of projects.
Ocean energy project developers in France must fulfil the following permitting and licensing process:

- A single permit regarding environmental issues, which includes an environmental impact assessment (EIA), if needed, one focusing on Natura 2000 impacts, and one dedicated to protected species, delivered by the Prefect. Within this permitting procedure, a public consultation is organized by the State;
- If located in territorial waters, a license to occupy the maritime public domain, which takes into account maritime safety and the use of maritime territories and is delivered by the Prefect. This licensing requires a public consultation which can be combined with the preceding process.
- For farms above 50 MW, an authorization to generate electricity delivered by the Ministry of Energy. This authorization is automatically delivered to the laureates of State calls for tender.

In addition, the developer signs a grid connection convention with the French Transmission System Operator (TSO).

MARKET INCENTIVES

Until May 2016, the Feed-In Tariff for ocean energy systems was set at € 173/MWh. In addition to this scheme, grants and reimbursable loans are awarded to prototypes and pre-commercial pilot arrays. As an example, the 2 tidal pilot arrays of the Raz Blanchard/Alderney Race of respectively 14 and 5.4 MW of installed capacity are under development with a total public support of €103 million.

In order to attract industrial investments, the next phase in policy (e.g. for commercial arrays) relies on calls for tenders, in a competition where a major part of the selection criteria relies on the assessed price per MWh.

PUBLIC FUNDING PROGRAMMES

In France, the general framework for the national public funding in MRE comes through the Investment for the Future Programme. Two main agencies are then involved in managing these funds through calls for tenders, namely ADEME (Environment and Energy Agency) and ANR (National Research Agency).

In 2016, newly awarded funds by ADEME have thus been directed to 4 pilot arrays of floating wind turbines (around 24 MW each, 3 in the Mediterranean Sea and 1 in the Atlantic Ocean) and 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 2016, ANR awarded financing to 9 MRE R&D projects throughout the "Institute for the Energy Transition" call for tenders. These public-private collaborative projects tackle technological bottlenecks and environmental issues.

The Public Bank of Investments (BPI France) also buys shares in SME's. For instance, in 2016 it was among the investors that increased by €8 million Sabella's capital.

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 and ONEM, 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. By a labelling process, they foster interest in collaborative projects that can apply to national funds (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 8 successfully financed collaborative MRE R&D projects in 2015 (€3 million state financing). 8 additional projects have been accepted for financing and will be launched in 2017. Below is a brief listing of the treated subjects in 2016:

BENTHOSCOPE2 - understanding and monitoring of MRE impacts on the benthic compartment via a measurement platform dedicated to passive acoustics;
EOLINK - proof of concept for an innovative floating wind generator;
HYD2M - Raz Blanchard hydrodynamics: measurements and modelling;
INDUSCOL - instrumentation and durability of glued multi-material structures for MRE systems;
PHYSIC - sediment transport processes in the presence of intense currents;
THYMOTE - tidal turbulence: modelling, field observations and tank experiments;
TROPHIK - ecosystem approach of MRE: modelling the role of offshore wind farms in modifying the functioning of coastal food webs and cumulative impacts;
OMDYN - dynamic cable for marine energy.

MET-CERTIFIED

In July 2016, the European Interreg 2 Seas monitoring committee accepted the €5.6 million the financing of the MET-CERTIFIED project for the development of international standards and certification systems for marine renewable energies.

MET-CERTIFIED aims to promote the development of projects for the recovery of marine energies that can be covered by an insurance contract, and therefore be financed. This requires the development of internationally recognized standards and certification systems, as well as the testing and verification of technologies according to standards for marine energy converters.
The project is conducted within the framework of a European public-private partnership. Ifremer in France contributes to the project through its Behaviour of Offshore Structures laboratory, responsible for "experimental testing" in the project.

MARINET2

In continuation of the MARINET project, MARINET2 has been approved funding through the Horizon 2020. This new project is due to start in early 2017 and will run for 4.5 years. While activities proposed under MARINET2 will follow the same formula as in MARINET, balancing networking/joint research/ and transnational access, the consortium and scope of work are expanded to include 39 partners in 13 countries with 57 facilities. www.marinet2.eu

THeoRem

Ifremer and ECN (Ecole Centrale de Nantes) have joined efforts to set-up a GIS named THeoRem in order to create a National Research Infrastructure related to hydrodynamic testing facilities. The objectives of THeoRem are:
- to coordinate activities of the two major French research centres operating hydrodynamic testing facilities for advanced research programmes in hydrodynamics at the European level;
- to facilitate the development of collaborative projects;
- to develop a common strategy in regards to the development, and associated investments, of the testing facilities; and
- to animate the industrial and scientific communities using these facilities (MRE, Oil&Gas, Shipbuilding, etc.).

MARINERG-I

The Marinerg-I project, submitted in response to the INFRADEV-02-2016 "Preparatory Phase and support to early phase of ESFRI projects" was accepted for funding in September 2016 and will start early in 2017. This project, led by the MaREI Centre at University College Cork (UCC) in Ireland, aims at preparing a proposal for a European Research Infrastructure supporting the development of Marine Renewable Energy that could be submitted to the next ESFRI call around 2019. Ifremer, on behalf of THeoRem, is the French partner in the consortium.

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

SEM-REV

As part of the experimental facilities of Ecole Centrale Nantes, SEM-REV has been developed through public financial support to validate & optimize both Wave Energy Converters and Floating Wind Turbines in real open sea conditions.
The SEM-REV package includes: land station, research centre and electrical substation, export cable (20 kV, 8 MVA, 24 optical fibres), and a 1 km² restricted marine area equipped with met-ocean instrumentation, an electrical subsea termination unit for 3 prototype connections and fully consented slots for testing.

SEM-REV CHARACTERISTICS

Water depth	32 m to 36 m LAT
Seabed	Sand (0.2-0.5 mm)
Export cable	8 MVA - 20 kV
3 test slots	24 optical fibers
Wave	3 Datawell buoys
Current tide	2 ADCP systems
Wind	2 meteo-buoys
Tidal range	6.2 m
Max tidal current (10 years)	0.7 m/s
Mean wave energy	12 kW/m
Extreme Hs (10 years)	8,3 m
Extreme Hs (50 years)	9,6 m
Mean Wind velocity	7,5 m/s (1h10m)
Extreme Wind (50 years)	29 m/s (1h10m)

Additional supporting facilities include: met- ocean data and analyses, design and installation verifications, maintenance in operational conditions, access to local marine stakeholders and environmental impact assessment. Projects currently deployed on the test site (2016 to 2018):

- FP7 Floatgen project (Ideol, Bouygues, Un of Stuttgart, RSK, ECN, Zabala): 2-year test of a floating wind turbine based on a concrete floater, a synthetic rope mooring system and a first dynamic umbilical;
- BPI France IHES project (Geps, Ifremer, ECN, Icam, SNEF): 2-year test of a new floating WEC concept including the new Pywec PTO (developed by Pytheas).

The **Interreg FORESEA** project (partnership: EMEC, Smart Bay, TTI and ECN/SEM-REV) was launched in 2016 with the goal to deploy 6 MRE technology components at SEM-REV between 2016 and 2019. SEM-REV is also part of the H2020 MARINET2 project approved in 2016 and the ESFRI MARINERG-I project awaiting final decision early in 2017.

SEENEOH

SEENEOH is an original estuarine tidal test site for full scale river and intermediate scale ocean tidal devices.
In Bordeaux, during spring tides the Garonne River tidal range exceeds 5 m and current velocities can reach 3.5 m/s, while currents above 1 m/s occur approximately 80% of the time. Depth at the test area is greater than 8 m. These characteristics allow the testing of full and/or intermediate scale machines relevant for the extensive global tidal market in rivers, estuaries and oceans.
Each of the three available berths is connected to an onshore substation. The berths are designed to accommodate tidal devices with either mounted or floating fixation types. The grid connection has a total capacity of 250 kW. Two berths have been operational since December 2016, and the third will be in February 2017.
The services offered by the SEENEOH test site to users comprise several elements, including the provision of a technical room in the land-based converter station for the installation of the user's energy conversion system, and monitoring of the prototype during the test campaign via a SCADA system.

OPERATIONAL PROJECTS

SABELLA

D10 - Ouessant

- Deployment in June 2015, isolated island grid connection in November 2015;
- First and currently only marine tidal turbine to have provided electricity to the French electricity grid;
- Removed from the water in July 2016 with validation of the turbine/base modularity designed to ease maintenance operations;
- End of the ADEME-funded demonstration project in cooperation with the Bureau Veritas and IFREMER;
- Qualification of SABELLA for the ICE project (Interreg trans-English Channel Brittany/Cornwall) for the use of the D10 tidal turbine for 2 to 3 years in the Fromveur current (Brittany).

HYDROQUEST

Hydroquest designs, manufactures and installs innovative hydrokinetic water turbine farms for rivers, estuaries and oceans, based on an internationally patented unique crossflow technology.

Hydroquest River 1.40 is the only grid connected fluvial hydrokinetic turbine in operation in France (2 years). For commercial-ready river applications, Hydroquest offers a range of two machines with nominal power ratings of 40 kW (Hydroquest River 1.40) and 80 kW (Hydroquest River 2.80). Projects are currently underway in France, Africa, Asia and South America.

Hydroquest River turbines can be adapted to any river profile with a minimum 2m depth. The turbines use a crossflow double vertical axis technology with an anti-debris grid system installed on the supporting structure, which deflects solid objects present in the water. The hydrokinetic turbine is fixed on a floating barge equipped with a hydraulic cylinder for positioning of the turbine in its submerged position (operation) or raised position (inspection, maintenance, transportation, production pause).

PAIMPOL-BRÉHAT TIDAL DEMONSTRATION PROJECT (BRITTANY)

EDF develops a tidal demonstration project located off the north coast of Brittany. The project involves the installation of two industrial-scale OpenHydro turbines delivering up to 1 MW power to the national grid.

- The project Phase 01 was dedicated to the test of Openhydro 16m diameter prototype “l’Arcouest” in stand-alone. This phase was achieved in 2014.
- The project Phase 02 consists of two Openhydro turbines, a subsea conversion system developed by GEEPC, an export cable of around 16 km length exporting power from the converter to an onshore substation located in the “Anse de Launay” and a connection system inter-connecting the equipments. The construction of the demonstration farm was completed in 2016, with the deployment and connection of all the equipments and the achievement of numerous functional tests. The two turbines will be recovered in 2017 for detailed inspection and maintenance, with the objective of redeploying and exporting power to the grid the same year.
- Paimpol-Bréhat will also host a Hydroquest prototype for a test at sea in stand-alone.

GUINARD ENERGIES

In 2016, Guinard Energies successfully deployed its Poseide on site power measurement device based on the MegaWattBlue design in the waters off Guyana. The MegaWattBlue technology doubles the recoverable energy for a given rotor size thanks to a specific shroud and rotor coupling. In parallel, the electrical power regulation system was validated.

PLANNED DEPLOYMENTS

Normandie Hydro

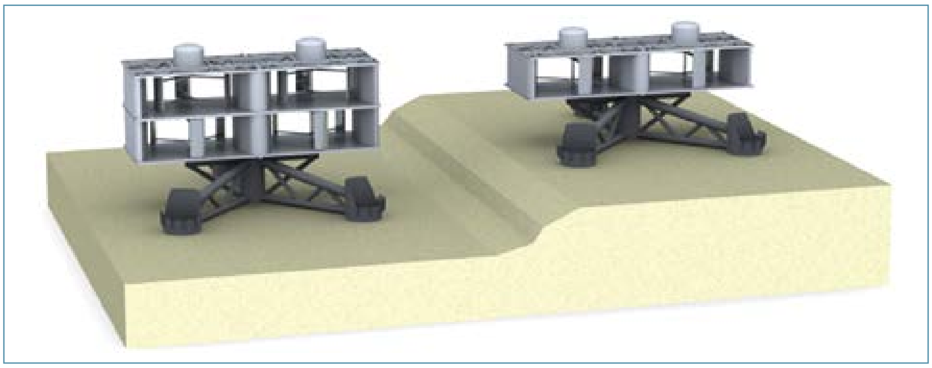
Tidal turbine pilot farm coordinated by the ADEME and financed by the Investments for the Future programme: Following the conception stage (2015), the Normandie Hydro tidal turbine pilot farm project located in the Raz Blanchard tidal race is progressing through the construction and installation stage (2016-2018). Planned for a 20-year period of operation, the 14 MW farm of 7 OpenHydro tidal turbines is coordinated by DCNS in cooperation with the French electricity provider EDF.

Guinard Energies

In 2017, the 250 kW MegaWattBlue tidal demonstration turbine will be deployed in the Ria d'Etel (South Brittany). This 4 m diameter, free-slewing ducted turbine will be commissioned using the patented "Camel" self-floating/ballasting gravity base.

OceanQuest project

HYDROQUEST and CMN, together with the University of Caen Normandy, were awarded funding in February 2016 from the Offshore Renewable Energy call for projects supported by the ADEME and Future Investments programme. The winning OceanQuest project will install a Hydroquest demonstrator turbine with a capacity of 1 MW on the Paimpol-Bréhat EDF test site in autumn 2017.



OTHER RELEVANT NATIONAL ACTIVITIES

Seanergy

The first annual international conference on marine renewable energies took place in Biarritz in the spring of 2016. In all, 3000 participants, 220 exhibitors from 15 countries participated in two days of presentations, seminars, meetings and exhibitions. The second edition of Seanergy is scheduled for 22-23 March 2017, in Le Havre.

INORE

The 2016 edition of the annual INORE young researchers' association symposium was held in Nantes on 12-18 June.

MRE Masters programme

The engineering school ENSTA Bretagne continues to offer a specialized masters degree in marine renewable energies, designed to complement a degree in engineering or a masters in mechanical engineering.

FWP Sea Tech Week

The annual international marine science and technology week event took place in Brest on 10-14 October 2016. This year's theme was centred on "Sea & Digital Technologies" with numerous conferences and round table events organized to discuss the issues.

GERMANY

JOCHEN BARD AND FABIAN THALEMANN *Fraunhofer IWES*

INTRODUCTORY NOTE

The further expansion of renewable energy is one of the main pillars in Germany's energy transition. To achieve this, a successful instrument to promote green electricity was conceived: the Renewable Energy Sources Act, which entered into force in 2000. This law had the aim of enabling new technologies such as wind and solar energy to enter the market with support provided by fixed tariffs, a purchase guarantee and priority feeding-in of renewable electricity into the grid. The Renewable Energy Sources Act has built a platform for the expansion of renewables, enabling them to emerge from a niche to become one of the mainstays of Germany's power supply, generating 25% of electricity. However, the rapid expansion also resulted in a rise in the surcharge imposed under the Renewable Energy Sources Act ("EEG surcharge"). In addition, it posed a growing challenge for the stability of the electricity grids and the security of our energy supply.

The amendment of the Renewable Energy Sources Act in 2014 was therefore an important step towards ensuring the continued success of Germany's energy transition. The revision particularly aims to substantially slow any further rise in costs, to systematically steer the expansion of renewable energy, and to bring renewable energy more and more to the market. It is clear that for energy-intensive industries, the price of electricity is a major factor in their level of competitiveness. It is vital that the competitiveness of electricity-intensive industries - which already pay high electricity rates in comparison to their international competition - is not jeopardised and that value creation and jobs are retained in Germany, because the economy's industrial core is of vital importance to prosperity and employment in Germany. At present, there are plans to alter certain aspects of the special equalisation scheme of the 2014 Renewable Energy Sources Act (inclusion of hardening plants and forges). The Federal Government adopted a corresponding bill on 1 April 2015.

The expansion of renewable energy in Germany is successful - renewables accounted for roughly 32% in 2015, and the policies now being put in place mean that their share is to rise to 45% by 2025. The 2014 Renewable Energy Sources Act (EEG 2014) paved the way for expanding renewables in a way that is both reliable and easy to plan, and that makes them fit for the market. The 2017 Renewable Energy Sources Act now heralds the beginning of a new stage of the energy transition - one that will be based on new rules: rather than being fixed by the Government, future rates of renewables funding will be determined by the market by means of dedicated auction schemes from 2017. This is because renewables have matured and are now ready to compete on the market. The new auction scheme is to ensure that the expansion of renewables proceeds at a steady and controlled pace and at a low cost. The legislation also enables us to make sure that the high level of market-player diversity that has characterised the energy transition will be upheld. The law gives the first-ever definition of a "citizens' energy company" and provides for these to participate in the auctions on simplified terms. Also, small installations are exempted from the auctions. The new (2017) version of the Renewable Energy Sources Act will enter into force on 1 January 2017.

The Federal Ministry of Economics and Energy (BMWi) is promoting research and development in the field of renewable energies within the framework of the energy research programme of the Federal Government. Projects are supported in wind energy, photovoltaics, deep geothermal energy, low temperature solar thermal, solar thermal power plants , hydropower and ocean energy and finally integration aspects of renewable energies in general.

HYDROPOWER AND OCEAN ENERGY

For the production of electricity from hydropower the natural flow of the water - primarily from rivers or reservoirs - is used. In the area of the seas, the tidal and the energy content of the currents and the waves can be used for the generation of electricity. The advantage of hydropower and ocean energy compared to wind energy and photovoltaics is seen in the fact that the energy can be provided with less fluctuation and can be predicted more reliably. Hydropower is a proven source of energy, but it is already used in most of Germany's suitable locations. The use of ocean energy, on the other hand, is still in the demonstration stage worldwide and is not considered suitable for use in Germany.

RESEARCH & DEVELOPMENT

In the public sector, around 15 R&D institutes and universities are involved into developing wave, tidal current and osmotic power mainly in the framework of European research projects. The National funding in the framework of the national energy research programme for renewable energies is open to ocean energy research. Up to now, around 10 technology projects related to the development of components and concepts for tidal turbines and wave energy components have been funded.

In July 2015, a consortium consisting of **SCHOTTEL HYDRO**, Fraunhofer IWES, the Institute for Fluid- and Thermodynamics (IFT) at the University of Siegen, Hamburg Ship Model Basin (HSVA) and Potsdam Model Basin (SVA), has started the project "TidalPower" which will run for three years. The aim of the project is to facilitate the deployment of the first prototype of the semi-submersible tidal power platform "TRITON" at the FORCE tidal research centre at the Bay of Fundy, Canada. In 2016, model tests of a 1:17 scale TRITON structure were performed at the Hamburg model basin as part of the project. The TRITON, developed by SCHOTTEL HYDRO subsidiary TidalStream Ltd., carries 40 SCHOTTEL Instream Turbines, reaching a total nominal power output of 2.5 MW. It will be built and delivered by SCHOTTEL HYDRO subsidiary Black Rock Tidal Power. The TRITON hull is currently being manufactured by Aecon Atlantic Industrial shipyard in Nova Scotia, Canada, and Schottel has started with the manufacturing of the 40 SIT 250 turbines. Deployment at FORCE, Bay of Fundy, Canada, is scheduled for 2017.

The Project "Development and Optimization of a Drive Train for Tidal Current Turbines" by **ANDRITZ HYDRO** with the objective to optimize the HS1000 turbine – a hub with single blade pitch and steel blades - was successfully completed in 2015 after running for more than two and a half years. Details of the project outcome have been published in the final report issued in September 2015. Three turbines of this design have been delivered to MeyGen project.

The **EPoSil project,** developing electro-active polymers (EAP) based on silicon for power generation was run by Bosch Rexroth with the aim to develop the EAP materials and manufacturing processes from 2012 to 2015. The wave energy application consists of a point absorber with a stack of silicone based electro-active polymer sheets as PTO. A point absorber scale model has been tested at the Hamburg model basin's wave tank. The public final report was issued in 2016.

The **NEMOS GmbH** develops a wave energy converter consisting of an elongated floating body, which is braced by three cables to the ocean floor. Excited by the movement of waves, it transmits mechanical energy to the generator by means of a cable. The generator itself is positioned at the tower of a wind turbine above the sea water level. Since August 2015, the NEMOS 1:5 test device at the Nissum Bredning Test Station for Wave Energy, Denmark, operates in full automatic mode, feeding energy into the grid. In November, testing of the first full scale components started at the Institute of Mechanical Handling and Logistics at the University of Stuttgart. In December 2015, a floating service platform was prepared at the port of Hanstholm, waiting for tow-out in 2017 (re-scheduled) to be utilized for anchor drag tests and installation works (source: www.nemos.org).

Wave power developer **SINN Power GmbH** successfully installed their first wave power module at the Port of Heraklion, Crete, Greece, in late 2015, and has generated power from ocean waves during a long-term field test since May 2016. 12 months after the first commissioning, SINN Power has taken in the wave energy converter module for another round of upgrades. The goal is to maximize energy generation and further improve durability of all components in the ocean environment. The upgrades are expected to reduce costs, increase performance and improve structural stability. Among others, they include new generators with more power output, more efficient power electronics, cost-improved, shock-absorbing generator mounting and improved end-stop buffering to absorb the impact of high waves. After the winter break, the third-generation wave energy converter module will be reinstalled for another round of long-term tests. These advanced tests serve as preparation for the planned installation of the floating wave energy converter array, also planned to take place in the Heraklion area after coordination with the local authorities (source: www.sinn-power.com).

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

TECHNOLOGY DEMONSTRATION

In addition to the projects mentioned above, major German utilities are active in the ocean energy sector with test installations and prototypes around Europe. There is no ocean energy installation realised in Germany yet and no plans for installations have been published.

INDIA

DR PURNIMA JALIHAL AND MR. PRASAD DUDHGAONKAR *National Institute of Ocean Technology (NIOT)*

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The technology development of ocean energy devices is the mandate of the Ministry of Earth Sciences (MoES). After becoming a member of the OES, MoES is encouraging NIOT to take up research projects with specific targets in conjunction with other countries and be part of subgroups of the OES. Efforts also are being taken up for evolving a unified approach by involving academia and other Government bodies like the Ministry of New and Renewable Energy (MNRE).

PUBLIC FUNDING PROGRAMMES

The Ministry of Earth Sciences under Government of India funds the programme on Ocean Energy and Desalination in NIOT. There are specific programmes and projects identified for technology demonstration and these are funded by the Ministry after an approval process. Some programmes like OTEC have been identified in the top Governmental levels and fall in the top-down approach. Technology development projects are generally proposed from institutes to the Ministry in a bottoms-up approach.

The Ministry of New and Renewable Energy focuses on power production by wind and solar with emphasis also on tariff fixation.

RESEARCH & DEVELOPMENT

The National Institute of Ocean Technology under the Ministry of Earth Sciences carries out research and development activities related to ocean energy. Relevant R&D projects are listed below.

RELEVANT R&D PROJECTS

Wave Energy:

Two types of floating wave energy devices, namely the backward bent ducted buoy (BBDB) and the wave powered navigational buoy, are being currently developed and optimized for off grid small power requirements in remote locations. A unidirectional impulse (UDI) turbine for wave energy conversion was developed with an optimum match between the BBDB and the turbine. The open sea trials of the BBDB with the optimized turbine led to successful power generation as per design.

The development of a wave powered navigational buoy is underway by carrying out numerical studies using computational fluid dynamics (CFD) principles and physical experimentation on small scale models in wave flume. The first prototype is ready for fabrication and will be tested off Chennai.

Pareto optimization studies using genetic algorithm have been carried out on the geometry of an existing bidirectional flow impulse turbine. Efforts so far indicate an improved turbine performance and further improvement is expected. A comparison between bi directional and twin unidirectional impulse turbines will be made for the final choice for scaled up devices.

OTEC:

India continues to carry out research in the area of ocean thermal energy conversion. The main focus of the research is on development of OTEC turbines, heat exchangers and deep sea cold water conduit. A state of the art laboratory to carry out experiments on various components of OTEC and LTTD is being setup in the campus of the National Institute of Ocean Technology at Chennai. OTEC cycle in this setup will be powered by a turbine that has been designed in-house. The facility is expected to be fully operational in the year 2017.

The low temperature thermal desalination plants set up on the islands by the National Institute of Ocean Technology continue to function and generate water.

These plants use diesel generators to supply power for the pumps. To avoid dependence on external power sources, the Government of India has decided to fund an OTEC powered desalination plant on an island in the Lakshadweep group in the Arabian Sea. The design has commenced and implementation will begin once the formal approvals are received in early 2017.

Marine Currents:

A small rating marine hydrokinetic turbine was developed through CFD analysis, laboratory testing and constant speed seawater channel testing. The turbine generated electricity and performed satisfactorily during the open sea trials conducted in 2016 on Andaman Islands in the Bay of Bengal. This turbine has worked in the tidal stream but can also be used for open ocean currents. A scaled-up turbine is being designed for installation in mid-2017.

The marine hydrokinetic turbines for Indian waters will have low speeds and medium range torques. Alternators for such combinations are not available in the market. To this end expertise has been developed in NIOT to design such alternators and they are being locally fabricated.

Floating current turbine tested on Andamans

BBDB sea trial with ϕ 196 mm UDI turbine off Chennai coast

TECHNOLOGY DEMONSTRATION

OPERATIONAL PROJECTS

Desalination plants in U.T. Lakshadweep using ocean thermal gradient:

Kavaratti Plant


Minicoy Plant


Agatti Plant

PLANNED DEPLOYMENTS

An ocean current turbine module with 1 kW average capacity is scheduled for deployment in mid-2017.

The design of an OTEC powered Desalination Plant at Kavaratti in the Union Territory of Lakshadweep has commenced and the scheduled completion is 30 months.

India is still in the early stages of development of ocean energy devices. However, success at the small scales in design as well as deployment has led towards scaling up. A lot of experience has been gained in OTEC and desalination using ocean thermal gradient. The first OTEC powered desalination once commissioned in Lakshadweep will be a pioneering effort and can pave the way for scaling up large self-powered desalination systems.

OTHER RELEVANT NATIONAL ACTIVITIES

Academic institutions, like the Indian Institute of Technology at Chennai, are working on wave energy. The Indo-Australian Marine Renewable Energy Workshop in collaboration with Swinburne Univ., Australia was held on 4-5 April 2016. Recommendations were to work together by considering not only physical-sciences and engineering aspects, but also socio-economic factors for integrating Coastal Protection with Wave Energy. The workshop has led to several joint papers in the field of ocean energy especially with one joint comprehensive work on marine energies for coastal areas co-authored by Indian, Australian and European representatives.

IRELAND

DECLAN MEALLY *The Sustainable Energy Authority of Ireland (SEAI)*

INTRODUCTORY NOTE

Ireland is 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. All relevant agencies and Government departments are working together to support this burgeoning sector and offering one single gateway for information and access to the ocean energy industry in Ireland. Ireland has a unique ladder of development and test site infrastructure, which was significantly enhanced in 2016. 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.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The Offshore Renewable Energy Development Plan (OREDP)

The Irish Government's Department of Communications, Energy and Natural Resources (DCENR) published the Offshore Renewable Energy Development Plan (OREDP) in February 2014 (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 over-arching vision of the Plan is "Our offshore renewable energy resource contributing to our economic development and sustainable growth, generating jobs for our citizens, supported by coherent policy, planning and regulation, and managed in an integrated manner" (DCENR, 2014). The Plan is divided into two parts. The first part deals with the opportunities, policy context and next steps, including 10 key enabling actions for the development of the sector. The second part focuses on the Strategic Environmental and Appropriate Assessment of the Plan.

The implementation of the OREDP will be led by the DCENR 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 Group reports directly to the Minister and the Plan will be reviewed in 2017.

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.

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 in 2017 will align the foreshore consent system with the planning system in order to streamline the EIA and AA processes for projects.

2016 saw two draft environmental guidance documents for the offshore renewable energy industry released for public consultation. These documents, one on the preparation of Environmental Impact Statements (EIS) and Natura Impact Statements (NIS) for offshore renewable energy projects and the other on Marine Baseline Assessments and Monitoring Activities, aim to ensure there is clear guidance for developers on environmental statements, data and monitoring necessary for deploying in Ireland's oceans, ensuring best practice is adopted in order to develop the industry in an environmentally friendly manner.

MARKET INCENTIVES

Under the Job Creation work-stream of the OREDP, one of the key actions is the introduction of Initial Market Support Tariff for Ocean Energy. It is envisaged that this will be equivalent to €260/MWh and limited to 30 MW for ocean (wave and tidal), focusing on pre-commercial trials and demonstration.

In July 2015 DCENR published an initial Renewable Energy Support Scheme Consultation, and are currently preparing for the next stage in the consultation process. The objective of this process is, where a clear need is demonstrated, to develop a new support scheme for renewable electricity to be available in Ireland from 2017 onwards, to support the delivery of Government policy, while taking account of the broader emerging policy context, such as the Energy Policy White Paper, the transition to the target market, the EU 2030 Climate and Energy Framework and State Aid guidelines, the Energy Union package and the European Energy Security Strategy. The development of the wave and tidal market support tariff is included as part of this process.

PUBLIC FUNDING PROGRAMMES

SEAI Prototype Development Fund

The OREDP reiterates the focus on stimulating industry-led projects for the development and deployment of ocean energy devices and systems through the support of the Sustainable Energy Authority of Ireland's Prototype Development Fund. The objectives of this programme are to accelerate and enhance support for the research, development, testing and deployment of wave and tidal energy devices.

Seventeen new projects were awarded grants in 2016, bringing the total number of projects to eighty-five since 2009. Such projects included physical tank testing of early stage wave energy convertor concepts, floating offshore wind platforms, and specialist software development.

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.

The first OCEANERA_NET joint call commenced in late 2014, and a number of Irish partners were involved in successful project proposals. A second Joint Call was launched in February 2016.

Ocean Energy ERA-NET Co-fund

The Ocean Energy ERA-NET Co-fund (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.

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 will be launched in 2017 and will be open to applicants from three European countries (Ireland, Spain, Sweden) and four regions (Brittany, Pays de la Loire, the Basque Country, and Scotland).

RESEARCH & DEVELOPMENT

Marine Renewable Energy Ireland (MaREI)

MaREI is a centre of excellence for marine renewable energy, supported by Science Foundation Ireland. 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 UCC, NUIG, UL, MU, UCD, and CIT, 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 2016, MaREI had approximately 130 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, to the value of €5 million.

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 projects are ORPC Ireland, UCC, and Letterkenny Institute of Technology.

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 2016.

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.

2016 saw the formal launch of the subsea observatory at the site, with a four kilometre cable providing a physical link to the shore at Spiddal, Co. Galway. The ocean observatory enables the use of cameras, probes and sensors to permit continuous and remote live underwater monitoring. The cable supplies power to the site and allows unlimited data transfer from the site for researchers testing innovative marine technology including renewable ocean energy devices. The installation of this infrastructure was the result of the combined efforts of the Marine Institute, SEAI, the Commissioners of Irish Lights, Smartbay Ireland and the Marine Renewable Energy Ireland (MaREI) Centre. The project was part funded under the Science Foundation Ireland (SFI) "Research Infrastructure Call" in 2012. The SeaPower platform, a quarter-scaled wave energy converter, was successfully deployed to the site in November 2016. The scaled wave energy converter has been feeding back both energy and survivability data since.

Atlantic Marine Energy Test Site (AMETS)

The Atlantic Marine Energy Test Site (AMETS) is being developed by SEAI to facilitate testing of full scale wave energy converters in an open and energetic ocean environment. AMETS will be located off Annagh Head, west of Belmullet in County Mayo and will be connected to the national grid.

It is currently envisaged that the site will provide two separate test locations at water depths of 50m and 100m to allow for a range of devices to be tested, though the potential to facilitate testing at shallower depths or the testing of other technologies such as floating wind is being investigated.

The infrastructure to support testing at AMETS continues to be advanced. Working in conjunction with SEAI, Mayo County Council upgraded port facilities in the area ensuring both local fishermen and developers ease of access. Planning permission for the onshore aspects of the site, including the electrical substation, was submitted in 2016. Crucially, the Foreshore Lease for AMETS was signed by the Minister of Environment Communities and Local Government in late 2015. This was the culmination of a detailed assessment and approval process and provides the legal basis for operating the test site.

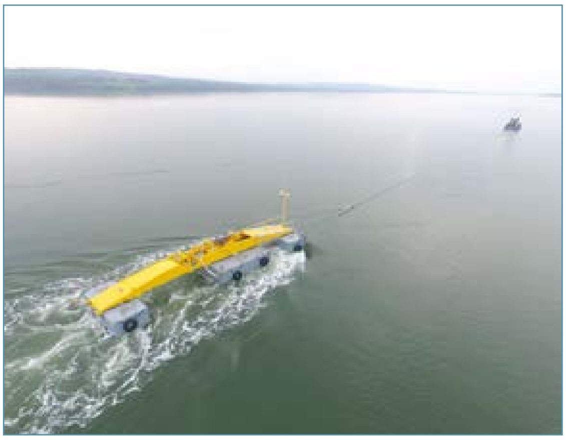
OPERATIONAL PROJECTS

SEAI's Ocean Energy Prototype Development Fund supports a range of technology demonstration projects. Recent examples include:

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.

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 phase 1 of the current project saw the device deployed to the quarter-scaled Galway Bay test site in November 2016. Since deployment, the company have been continually receiving wave energy data and assessing survivability in open sea winter conditions. Phase 2 is expected to commence in 2017.

SeaPower Platform at Foynes Port, Co. Limerick in 2016



The SeaPower Platform being towed to the Galway Bay test site in 2016

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 2017.

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 two workshops in 2016, held in Dublin and Edinburgh, 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 next OPIN event is due to take place in Belfast in March 2017.

The Ocean Energy Ireland Portal

The portal, designed by SEAI and the Marine Institute with input from numerous other groups, acts as a 'sign-post' to guide you through the supports available in Ireland for the development of 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 is continuously updated, and 2016 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. A new inventory for Environmental Planning was added to the website, which will aid developers researching testing and deployment in Ireland. The updated Ocean Energy Supply Chain Database was published in summer 2016, and currently features 120 businesses. www.oceanenergyireland.com

ITALY

LUCA BENEDETTI *Gestore dei Servizi Energetici - GSE S.p.A.*

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

According to the Italian National Renewable Energy Action Plan (NREAP), the Ocean Energy total contribution (in terms of installed capacity) expected to meet the binding 2020 European Renewable Energy Sources (RES) targets will be of 3 MW in 2020. For this reason, the Italian increasing interest in the exploitation of wave and tidal technology to produce clean and renewable energy can be recognized both in Government initiatives (e.g. one of the highest incentive for such sources worldwide) and in the research and development activities carried out by public and private players. Mainly universities and companies specialized in research and innovation are involved in R&D in this field. Thanks to those efforts, Italy is indeed at the forefront of research, development and demonstration at a prototypal level. Such leadership has recently been recognized by the Chilean Government's economic development organization CORFO (Corporación de Fomento de la Producción); Enel Green Power (EGP) from Italy and DCNS from France have been selected to set up a ground breaking global centre of marine energy R&D excellence in Chile, named Marine Energy Research and Innovation Centre (MERIC). MERIC's applied research and development work will focus on key sources of marine renewable energy, such as tidal power and wave power.

REGULATORY FRAMEWORK

The Ministerial Decree on renewable energy sources (DM 23 June 2016) updated the support scheme previously regulated by DM 6 July 2012. This Decree has, in turn, reviewed the preceding framework based on Feed-in Tariffs and Green Certificates for renewable plants (other than PV) in operation starting from 1 January 2013 (with capacity ≥ 1 kW). DM 23/6/2016 (in continuity with DM 6/7/2012) 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 to 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).

MARKET INCENTIVES

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 receive, instead of the incentive, 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 GSE (the Italian Energy System Operator, 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.

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

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

In 2016, a single initiative, with capacity of 49,5 kW, entered into operation and requested direct access to incentives. For wave and tidal energy power plants, the total annual capacity (MW) eligible to access to registries from 2013 to 2015, and so to obtain the incentives, is 6 MW. However, no plants were admitted for incentives in 2016 registries. It should be reminded that a 99 kW project was admitted in 2014 registries (under DM 6/7/2012), and it still keeps the right to be realized and to access incentives, although it has not been built yet. The Decree does not provide Dutch Auctions for 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	CAPACITY (kW)	CONVENTIONAL PLANT'S LIFE (YEARS)	FIXED TARIFF (€/MWH)
Oceanic (tides and waves)	1< P ≤ 5000	15	300

RESEARCH & DEVELOPMENT

KEY R&D INSTITUTIONS AND RELEVANT R&D PROJECTS

Key players involved in research regarding the exploitation of marine energy to produce energy are universities and research centres. Among these, the University of Naples "Federico II" is distinguished for its GEM project started in 2003. In fact, the public/private consortium SEAPOWER Scrl (www.seapowerscrl.com), formed by a private company and the University of Naples, thanks to the collaboration between ADAG applied research group of the Department of Industrial Engineering, University of Naples Federico II and Eng. Nicola Giorgio Morrone, developed one of the most attractive projects of the last period in the field of renewable energy production using marine sources, *GEM: The Ocean's Kite* (http://www.seapowerscrl.com/ocean-and-river-system/gem).

The SEAPOWER public/private consortium is waiting for the final permit to set up and manage a real test field laboratory in the Strait of Messina, open to Italian and foreign companies for testing their tidal current devices. The laboratory will provide assistance in deploying the devices, data handling and certification for the prototypes installed and tested in the area available to the consortium. The consortium is waiting for the final permit to build the laboratory.

Umbra Cuscinetti S.p.A., parent company of Umbra Group (www.umbragroup.com), is an Italian manufacturing company leader in the production of ballscrews, bearings, rotary generators and Electro-Mechanical Actuators (EMAs) for aeronautical, industrial and energy applications. Through a conscious technology transfer strategy and based on the EMAs architecture, Umbra has been developing an Electro-Mechanical Generator (EMG) for converting linear motion into electricity. Such technology is required by a wide range of ocean energy systems and is a step change innovation in the Power Take-Off (PTO) application. The EMG is based on the integration of a ballscrew, which converts linear motion into rotary motion, and a permanent magnet generator, which converts rotary motion into electricity. This compact and robust design results in a reliable and efficient product that is currently under development for different power ratings (from 2 kW to 250 kW) and working environments (EMG completely submerged in marine water, acting above the sea surface or acting in a protected environment). The EMG is entirely designed, manufactured and assembled inside the facilities of Umbra and relies on existing tools/processes and an established supply chain.

The development of the REWEC energy conversion technology is underway at University Mediterranea from Reggio Calabria. The first full scale prototype of a U-Oscillating Water Column (U-OWC), whose industrial name is REWEC3 (Resonant Wave Converter, type3), is currently under construction in the Port of Civitavecchia (Rome).

Among research centres, CNR (Italian National Research Council) and ENEA (National Agency for New Technologies, Energy and Sustainable Economic Development) are involved in several projects and collaborative programmes to support the development and demonstration of key technologies. Some of these projects are mentioned in the following sections.

In 2016, Umbra has been involved in a number of projects related to ocean energy:

- **International project "ReBaS – Recirculating BallScrew generator"** - Wave Energy Scotland call for Innovative PTO solutions, Stage 2 (2015-2016): In this project, Umbra has designed and manufactured a 12 kW (rated power) EMG prototype for wave energy applications together with a point-pivoted Wave Energy Converter (WEC) buoy. The PTO prototype undertook both performance and extended dry tests at Umbra's facilities, and wave tank tests at the University of Naples "Federico II", where it was connected to the WEC. During these activities, the EMG measured average efficiency was in the range 70%-87% for all the tested conditions and resulted to be independent of the wave peak frequency and spectrum shape. Furthermore, the EMG survived load ratios up to 15 and performed more than 2 million cycles without showing signs of wear or damage. The project was developed in collaboration with SeaPower Scarl and Hebrides Marine Services Ltd., collecting knowledge Umbra acquired in the design of EMG and WECs through previous national and regional funded projects. Now, Umbra Group is preparing an application for transition to Stage 3, which foresees sea trials of a 90 kW WEC.

- **Regional project "WE-BACK"** - Legislative Decree 598/94 Umbria Region (2015-2017): In this project, Umbra is undertaking further R&D activity on the EMG. In particular, activities concerning the development of critical components, design methods for high loads and number of cycles, solutions for resistance in marine environment. A list of the projects that Politecnico di Torino (POLITO) has managed/currently manages along with a brief description regarding the objectives of each project is given below:

- **National project "GENERA"** - H2020 – PON MISE National Operative Plan of the Italian Ministry for Economic Development (2017-2019): Within this project, Umbra Group will conduct feasibility studies concerning the application of the EMG for wave energy, tidal energy and energy recovery from vibration damping. Concerning wave energy, the installation of a 60 kW EMG prototype coupled with a point-pivoted buoy along the Italian coast of Campania is also planned. One of the main goals of the project is to develop appropriate hardware and software solutions for an advanced and efficient control of the EMG power generation. The project is in collaboration with SeaPower Scarl and Electro Motor Solutions Srl.

Besides these above-mentioned R&D projects, the Enel Green Power (EGP) group is supporting other relevant initiative, as following:

- **SEAWARD** (H2020 LCE-15-2016) - *SEtting up An optimal WEC Array configuration for Real environment Demonstration*: the SEAWARD project aims to demonstrate the commercial attractiveness of Inertial Sea Energy Converters (ISWEC) through the design, manufacturing and demonstration of an array of 5 machines in the Canary Islands.

- **SUBLIME** (CEF Transport 2016 - Connecting Europe Facilities) - *SUstainable port moBiLity through the Implementation of WaveSax Marine Energy technology in European ports (SUBLIME):* the Global project consists of the development of the "ecological MoS terminals" by implementing the innovative WaveSax technology for the production of energy from renewable sources (marine waves), within the harbour.

Other R&D European funded projects:

SINGULAR (FP7-ENERGY-2012) - Smart and Sustainable Insular Electricity Grids Under Large-Scale Renewable Integration - A large share of the recent renewable energy sources (RES) installed capacity has already taken place in insular electricity grids, since these regions are preferable due to their high RES potential. However, the increasing share of RES in the generation mix of insular power systems presents a big challenge in the efficient management of the insular distribution networks, mainly due to the limited predictability and the high variability of renewable generation, features that make RES plants non-dispatchable, in conjunction with the relevant small size of these networks. The Smart Grid Initiative, integrating advanced sensing technologies, intelligent control methods and bi-directional communications into the contemporary electricity grid, provides excellent opportunities for energy efficiency improvements and better integration of distributed generation, including RES, such as wind and photovoltaic systems, coexisting with centralized generation units within an active network. POLITO is studying the possible integration of wave energy production in various applications to grid connected renewable energy generation.

MaRINET (2011–2015; http://www.fp7-marinet.eu/) coordinated by Cork University College (Ireland), gathered 28 among leading European Institutions with recognised expertise and testing capabilities for ocean energy systems. A key action within MaRINET has been the Trans-national Access (TNA) mechanisms, with hundreds of programmes receiving grants for device testing in one of the 48 facilities made available by project partners. Italy contributed to this project with three partners (CNR-INSEAN, University of Firenze and University of Tuscia), that hosted several TNA programmes. Italy was also among the countries with the largest number of TNA programme applications during the project.

TECHNOLOGY DEMONSTRATION

OPERATIONAL PROJECTS

GEM project

GEM, the Ocean's kite, has been patented and the concept consists of a submerged floating body linked to the seabed by means of a tether. The main hull houses electrical equipment and auxiliary systems. Two turbines are installed outside the floating body and are exposed to the external currents.

Due to a relatively safe and easy self-orienting behaviour, GEM, The Ocean's Kite, is a good candidate to solve some problems involved with oscillating and reversing streams, typical of tidal current. An additional advantage of its configuration is related to the possibility of avoiding the use of expensive submarine foundations on the seabed, because these are replaced with a flexible cable connected to a single mooring point. Releasing the anchorage cable allows the system to pop-up for easy maintenance. A special diffuser (shroud) has been designed to double the output power keeping the blade length small.

After several numerical investigations, a series of experimental tests on two different scaled models has been carried out in the towing tank of the Department of Industrial Engineering at the University of Naples. The models tested were completely instrumented so that a dynamic behaviour and the off-nominal working conditions were investigated. The real scale prototype system of 100 kW, with 5 knots of water current speed, has been built and has been deployed nearby Venice in a very slow speed current of about 3 knots downscaling the power to 20 kW. This prototype has been built by a consortium of Venetian companies thanks also to a financial contribution of Veneto Regional Authority. The real field tests have demonstrated the fully correspondence of the system behaviour with respect to what had already been measured on the 1:5 model during the test campaign in the naval towing tank. A full scale prototype of 200 kW at 2.5 m/s water current speed is being designed and will be deployed in the Strait of Messina to definitively assess all the performances of the system.

THE KOBOLD TURBINE

The "Kobold Turbine" has been developed since 1998 by ADAG Group of the Department of Industrial Engineering, University of Naples "Federico II", in collaboration with "Ponte di Archimede international Spa", a company that works in the field of research and development into alternative and renewable energy sources, specialising in the environmental aspects of this work. The Kobold consists of a submerged vertical-axis turbine for exploitation of marine currents, installed in the Strait of Messina, 150 metres off the coast of Ganzirri since 2002. The realization of the Enermar prototype has been financed by Ponte di Archimede Company, together with a 50% fund paid by the Sicilian Region Administration (Regione Siciliana), in the framework of European Union Structural Funds. This project has been disseminated among the developing countries in which the United Nations Industrial Development Organization (UNIDO) operates and the first three countries that expressed interest were the People's Republic of China, the Philippines, and Indonesia. A joint-venture was created, under the auspices of UNIDO, between "Ponte di Archimede" and the Indonesian Walinusa Energy Corporation.

A prototype is being built and will placed on the Lomboc Island (the island immediately at east of Bali), where it could feed energy to a small village. The Indonesian plant will have blades length 7 m (chord 0,4 m), and diameter 5 m (intercepted area 35 m^2). The power could be about 120-150 kW. The Ponte di Archimede company has now transferred its assets to the Horcynus Orca Foundation with the aim to leverage on the experiences gained with Kobold and the local workforce in the area to create a centre of excellence in the marine energy space.

40SOUTH PROJECT

Enel Green Power (EGP) has bought the H24 wave energy device from the Italian company 40South Energy. H24 represents the first EGP's wave energy harvesting device as the company lays the groundwork for the development of a new technological line with 'huge potential'. The 50 kW H24 machine was deployed as part of Marina di Pisa project off Tuscany, Italy. It consists of a guiding part located on the sea floor, or on a support structure, and of a moving part above it, which moves according to waves. H24 device can behave as both a tidal and wave energy generating unit, but for this particular project it will harness the energy of the waves to produce electricity.

ISWEC PROJECT

Sea waves are one of the most interesting and well distributed renewable energy sources in the world. At the current state of the art, all the existing sea wave energy conversion systems are designed to operate offshore, mainly in the oceans where the waves' height is definitely high. In the Mediterranean Sea, waves are generally low, except under particular meteorological conditions. Thus, it is necessary to develop devices that can exploit other properties of the waves instead of their height, like wave slopes. The mechanical conversion system, called ISWEC, that will be used for the development of the project has been analysed by Politecnico di Torino and results show that the system possesses good potential for energy conversion. ISWEC device is composed mainly of a floating body with a slack mooring to the seabed. The waves tilt the buoy with a rocking motion that is transmitted to the gyroscopic system inside the buoy. The gyroscopic system is composed of a spinning flywheel carried on a platform.

Trials at various levels have been carried out: in the first phase, a set of "dry tests" has been done on a controlled position mobile platform; in the second phase, a series of tests have been performed in the INSEAN wave tank, with suitably generated and controlled waves. Finally, the system has been placed and tested on Pantelleria Island for the real sea tests. Further tests will be carried out in order to develop and tune optimized control algorithms. In August 2015, the first ISWEC 1:1 scale device has been moored 800 m from the coast of Pantelleria Island in a water depth of 35 m.

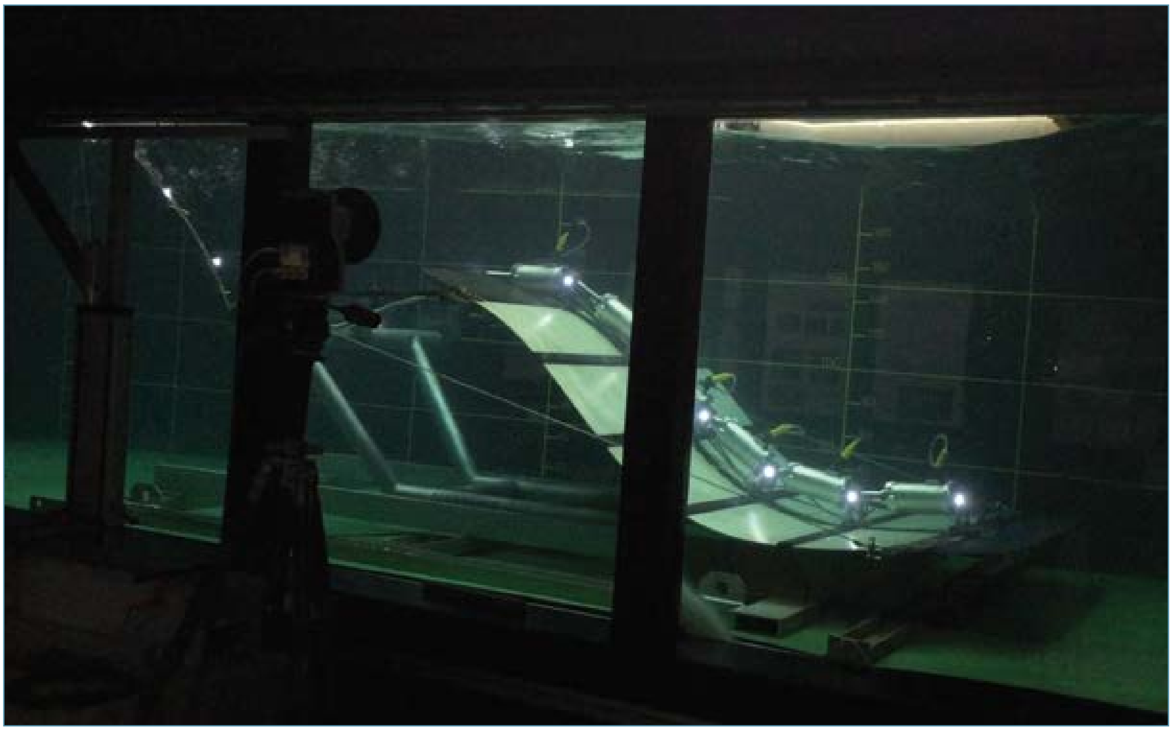
REWEC PROJECT

Among the wave energy converters, the Oscillating Water Column (OWC) system is the most widespread: such system consists of an air chamber with a seawater inlet and an air discharger. If seawater moves as a result of the vertical motion of external waves, then the seawater within the OWC moves as well. This movement within the system generates air pressure, which produces power to turn the turbine in the air discharge port. In this light, EGP is evaluating a particular onshore OWC system to test together with a Reggio Calabria University Spin-off, Wavenergy in Central Italy; the system is called REWEC (Resonant Wave Energy Converter), already built in Civitavecchia Port.

PLANNED DEPLOYMENTS

Umbra aims to deploy two temporary installations of a point-pivoted WEC buoy within two R&D projects: in 2017, the components will be prepared and 2018 will see the deployment in the Mediterranean sea of a 60 kW unit and of a 90 kW device on Orkney Islands. In early 2016, Umbra has started collaboration with the French start-up EEL Energy (http://www.eel-energy.fr/en). This company has been developing an original tidal energy device that consists in a flexible membrane which, actuated by tidal currents, oscillates longitudinally with respect to the current direction. The oscillations are damped by several EMGs placed on the membrane backbone.

A small scale device prototype, featuring six 2 kW EMGs, has already undertaken two laboratory test campaigns at IFREMER (http://wwz.ifremer.fr/institut_eng/) that have shown very promising results; further test campaigns are scheduled for 2017. Umbra and EEL Energy are now preparing a second prototype version that will undergo sea trials in 2017-2018. A first test in real environment is planned for October at SEENEOH (http://seeneoh.com/), in Bordeaux. The final goal is to deploy a 1 MW prototype by 2019-2020, thanks to the support of 3.7 million received from the French Programme d'Investissement d'Avenir (PIA - Future Investment Programme) and future European Union (EU) funding. After the deployment of the first ISWEC device, W4E is planning to install a second Gyro, doubling the amount of energy from the sea.



JAPAN

YASUYUKI IKEGAMI *Institute of Ocean Energy, Saga University*

SUPPORTING POLICIES FOR OCEAN ENERGY

Aiming to promote a comprehensive and systematic implementation of policies relating to the ocean, the Japanese Government enacted the "Ocean Basic Law" in July 2007. Based on this "Ocean Basic Law", the cabinet later issued the "Basic Plan on Ocean Policy" in March 2008. Since April 2013, the second "Basic Plan on Ocean Policy (BPOP)" has been in effect and will continue through March 2018, also based on the "Ocean Basic Law".

The Second Basic Plan on Ocean Policy states the importance of the aim 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." Considering this, the Government has decided to set the following as its basic stance and approach in adopting the development of the new Basic Plan on Ocean Policy:

1. International cooperation and contribution to the international community;
2. Wealth and prosperity through ocean development and utilization of the sea;
3. Evolving from a country protected by the sea to a country that protects the sea;
4. Venturing into the unexplored frontier.

Under the section of the BPOP 'Utilization of Sea', as it relates to number 2 above, Renewable Ocean Energy has been planned including 'wave energy, tidal energy, ocean current energy, and ocean thermal energy'.
All Renewable Ocean Energy projects based on the 2nd BPOP have been progressing and are scheduled through March 2018.
In 2016, discussions have been started to plan the next 3rd BPOP (five years) for promoting 'Utilization of Sea', including Ocean Energy.

RESEARCH & DEVELOPMENT

Renewable Ocean Energy Projects supported by the New Energy and Industrial Technology Development (NEDO), the Ministry of the Environment (MOE), the Ministry of Education, Culture, Sports, Science and Technology (MEXT) have been progressing.
Through NEDO projects, they have encouraged the R&D for wave energy, tidal energy, ocean current and ocean thermal energy conversion. In 2016, under a NEDO project, an ocean tidal current project has been undertaken by IHI Corporation, Yokyo University, Mitsui & Co., Lt., with an eye towards operation in 2017. The system is a twin-type configured with a pair of 50 kW power generators. The turbine diameter is about 10 meters with the total length of the floating body at about 20 meters. A practical system is assumed to be 2 MW (two 1000 kW units) with a turbine diameter of about 40 meters. The targeted generation cost is 20 yen per kWh.

TECHNOLOGY DEMONSTRATION

A consortium consisting of Kyuden Mirai Energy Co., Inc, Nippon Steel & Sumikin Engineering Co., Ltd., NPO Nagasaki Marine Industry Cluster Promotion Association and Open Hydro Technology has been selected by the Japanese Ministry of the Environment to supply a tidal turbine system for installation in the Okinawase Seto area of Goshima City, Nagasaki. Japan was selected as the business operator. The aim of this demonstration project (2 MW) is to establish technologies conforming to domestic environments and technical standards, target for early practical application of tidal current power generation in Japan. The implementation period is 2016 to 2019.

MEXICO

RODOLFO SILVA-CASARÍN, JUAN CARLOS ALCÉRRECA HUERTA AND ELIZABETH RODRÍGUEZ AGUIRRE
Universidad Nacional Autónoma de México

INTRODUCTORY NOTE

For more than a decade, Mexico has been working in the development of electricity generated by wind and solar resources. In 2014, these initiatives were extended to include marine energy exploitation and in 2016 the final agreements for the creation of the Mexican Centre for Innovation on Ocean Energy (CEMIE-Ocean) were reached. This initiative aims to produce collaboration between the Government, academia and industry in scientific research and the applied technology to harness ocean energy and train personnel.
It is hoped that the investigations already carried out will produce successful results now that several tests have been completed and a 1:1 scale model constructed. Two of the major challenges in accelerating the process of marine energy are related to the global price of oil and the lack of environmental regulations. Although, with the new strategies, such as the new CEMIE-Ocean, a long term policy has now begun.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The mechanisms for the development of policies, programmes, projects and actions for the use of renewable energies, including ocean energy, are part of the National Strategy for Energetic Transition and Sustainable Energy Usage (ENTEASE), developed in 2011, and are open to annual revision. Heading the National Strategy is the Secretary of Energy (SENER), along with all public sector institutions and the Federal Public Administration aligned with the Energy Transition Law and sustainable energy programmes.
The ENTEASE has three guiding principles: i) guarantee energy supply, ii) efficiency in the economic and productive means of harnessing sustainable energy, and iii) environmental sustainability. The objectives around these principles are intended to ensure efficient, safe and sustainable growth, the evolution of current energy systems to meet energy needs and the economic and social development of Mexico.

REGULATORY FRAMEWORK

The current regulatory framework is based on the Law for the Usage of Renewable Energies and the Financing of the Energetic Transition (LAERFTE). The Regulatory Commission of Energy (CRE) has introduced a specific regulatory framework for renewable energies and published conventions and contracts to regulate the energy generation according to their capacity range, i.e. small (0-10, 0-30 kW), medium (0-500 kW) and large-scale (>500 kW). Regulations concerning connection to the National Electric System have been developed since 2011, controlling the access of renewable energy projects to existent infrastructure.
For ocean energy systems there are currently no specific regulations in Mexico. However, its contribution to the energy sector is regulated by laws related to the usage of these natural resources and those for energy usage, such as the Political Constitution of the United Mexican States, LAERFTE, Law of National Waters, Law for Sustainable Usage of Energy, Organic Law of the Federal Public Administration, and Law of the Regulatory Commission of Energy. In addition, regulations based on international trade and agreements, such as the UN Convention on Climate Change and the Kyoto Protocol, are adhered to.

MARKET INCENTIVES

Incentives have been introduced by the Mexican Government for the installation of infrastructure and use of renewable energy, including ocean energy in all its forms.
Tax reductions (up to 100%) on taxes due on the acquisition of machinery and equipment for the generation/conversion

of energy from renewable energy sources. This incentive was established by the Federal Government and is supported in the Law of Income Tax (ISR).

A system of Carbon Credits has been agreed upon by the Federal Commission of Electricity (CFE) and the Mexican Stock Exchange (BMV), an exchange mechanism of carbon offsets. Greenhouse gas emissions will be regulated for each type of industry, so that companies that are able to generate clean energy can sell their carbon credits to capitalize their inversion.

Compensation for the services of renewable energies for which the CRE establishes the amount of the compensation that the CFE will pay for the services given. This allows the entrepreneur to estimate the price that will be paid for each kilowatt produced. Furthermore, the methodology for the price estimation benefits projects with renewable energies.

While these incentives are important for the development and encouragement of the use of renewable energies, further incentives are to be explored to accelerate the growth of this sector.

PUBLIC FUNDING PROGRAMMES

Resources from the public sector are channelled through funding programmes, including:

- The S**ectorial Fund CONACYT-SENER for Energy Sustainability** to foment scientific research and applied technology, as well as the adoption, innovation, assimilation and technological development of renewable energy, energy efficiency and development of clean technologies;
- The **Fund for the Energetic Transition and the Use of Renewable Energies** for the financing of projects aligned with the Mexican National Strategy for Energetic Transition;
- The **Fund for Projects of Microgeneration and Cogeneration of Electric Energy** up to 500 kW finances up to 100% for micro- and cogeneration of electric energy, as well as the acquisition of equipment and systems for use in renewable energy projects;
- **Credits for the Productive Public Investment to Municipalities** for the development of energy saving projects, for the use of renewable energy and for technological innovation;
- A **fund for Technological Development projects which impact in the Market and use Energy Safely and Efficiency** for the development of cogeneration projects of up to 500 kW alternative energies.

RESEARCH & DEVELOPMENT

The main research/development projects are:

- The design of a WEC was completed. Numerical and experimental modelling was carried out and a module was constructed for a wave height range of 0.5-1.5 m with wave periods of 5-7 s, with a potential capacity between 100-200 kW and a cover area of about 50 m2. This device will be installed in 2017 in the port of El Sauzal;
- In 2016, the “Thematic Network of Innovation in Ocean Energy” was created in order to enhance links between the different agents involved in the development/application of technology and for the integration/assimilation of ocean energy.

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

As yet no open sea test site facilities have been fully developed to include grid connection, nor has there been any deployment of sensors for measuring the performance of devices as ocean energy, exploration has only had a serious impulse in recent years.

One open sea test site has been used for small scale, informal research activities, at the Station Unit of the National Autonomous University of Mexico (UNAM) at Puerto Morelos in Yucatan, South East Mexico. The site facilities have allowed the implementation of small scale prototypes in a safe area where supervision from the Research Institution and the University is easy, as well as the monitoring of the performance of the device.

An open sea test site was designated in 2013, in North-western Mexico, at the port of El Sauzal, close to Ensenada in Baja California, for testing Wave Energy Converters (WECs). The installation site was selected considering the: a) the wave energy potential of the site, b) its proximity to a urban area with the necessary infrastructure for manufacturing, as well as several Research Centres, c) the low probability of extreme waves and hydro-meteorological events (e.g. hurricanes, storms), d) environmental impacts considering that testing in minimized by existing infrastructure, e) land and sea access points, f) the port provides a sheltered area for the electromechanical components of the devices. Further open sea sites are planned, most of them located on the Mexican Pacific, for which wave, current and tidal energies can be tested.

OPERATIONAL PROJECTS

As of 2016, no operational projects have been developed in Mexico in terms of technology demonstration. Existing technology for ocean energy has been developed worldwide but not for Mexican conditions, so that research and applied technology must address national needs.

PLANNED DEPLOYMENTS

A mechanism and device to capture wave energy in NW Mexico is being developed as the result of the collaboration between industry (Exclusive High-Tech [DINA]) and academia (Engineering Institute-UNAM). Up to now, the design has been tested with numerical models in order to meet the performance needed for Mexican waters (including extreme events, such as hurricanes), so that, prior to scaling and placement in the ocean, errors are minimized and costs reduced. The device will be placed close to the facilities of the port El Sauzal, Baja California, with a planned installed capacity of 100-200 kW. Scaling of the device can later produce an installed capacity of 1.0 MW. Tests and laboratory experiments will be conducted during 2017.

OTHER RELEVANT NATIONAL ACTIVITIES

The Mexican Centre for Innovation on Ocean Energy (CEMIE-Ocean) will formally start activities at the beginning of 2017. The Centre will co-ordinate the work of 41 Mexican institutions, academies and companies into the research and development of applied technology for the harnessing of ocean energy.

Current and Tidal Energy:

- Resource evaluation, which includes the development of a national atlas of energy potential and socio-economic-environmental studies in regions with most energy potential;
- Regional characterization, which includes the development of the potential of tidal and hydrokinetic energy in the Gulf of California, the design of hydrogen electrolyzers for energy storage, and performance evaluation.

Wave Energy:

- Wave energy characterization, which includes conceptual WEC design, theoretical and numerical studies and laboratory experiments with small and full scale prototypes. This will be a device designed for Mexican waters where high- efficiency devices are required.

Salinity Gradient:

- Resource evaluation, which includes elaborating a national atlas of salinity field to identify sites with exploitation potential and conducting socio-economic-environmental studies in the areas with greatest potential;
- Prototype design will include laboratory materials and techniques and adapting existing national capabilities and resources.

Ocean Thermal Energy:

- Resource evaluation, which will include making a national atlas of temperature fields, carrying out viability studies, monitoring thermal gradients in potential sites with thermistor chains and evaluating efficiency, technical-environmental and socio-economic impacts.

MONACO

HE MR BERNARD FAUTRIER *Government of Monaco*

INTRODUCTORY NOTE

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, the management of resources and the reduction of greenhouse gases and also a specific policy towards the establishment of a sustainable city.
The Principality of Monaco joined OES in June 2013. This action was part of the Government concerns for combating climate change and recognizing the relevance of international cooperation. Monaco is a coastal country with 2,02 km^2 of area, bordered by the Mediterranean Sea, with a coast length of 3829 m.
In Monaco, ocean energy projects have been demonstrated through the usage of sea water heat pumps to generate energy.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The Government pursues a decisive sustainable development policy aimed at achieving full compliance with the Principality's undertakings, in particular with the Kyoto Protocol. 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.

Carbon neutral by 2050

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 directions 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, two dedicated funding instruments have been created:

- The Energy-Sustainable Development Fund. The money is generated through the sale of electricity and creates funds for the promotion of renewable energies and other sustainable development objectives.
- The National Green Fund

Then, 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 and the department of the environment, the marine police and one NGO: Association Monegasque pour la Protection de la Nature that will be in charge of the production and management control plan.

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

Various buoys have been installed in partnership with the National Centre for Archiving Swell Measurements and the department of public works. Four types of data are measured: height, direction and frequency of waves and temperature of the water surface.
Live data is available on the website: http://candhis.cetmef.developpement-durable.gouv.fr/
This operation is mainly linked to Monaco's six-hectare offshore extension project.

TECHNOLOGY DEMONSTRATION

Monaco wishes to develop ocean energy. Currently, sea water heat pumps produce a significant share of the Principality's energy needs.
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. 75 sea water heat pumps produce 20% of the energy consumed in the Principality (about 187.6 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.
The number of sea water heat pumps is expected to increase in the near future due to some on-going projects.

OTHER RELEVANT NATIONAL ACTIVITIES

EVER is the annual exhibition and international conference event on Ecological Vehicles and Renewable Energies, held in the Grimaldi Forum, Monte Carlo, Monaco: http://conference.evermonaco.com/

NETHERLANDS

JOS REIJNDERS *RVO – Netherlands Enterprise Agency*

INTRODUCTORY NOTE

The potential of ocean energy has been studied since the 80s and recently the Ministry of Economical 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).
Many techniques and projects have been developed, resulting in the following highlights:

- The 1.25 MW tidal power plant in the Eastern Scheldt, which was installed by the end of 2015, performed very well in 2016. The T2 tidal & free flow turbine of Tocardo has been awarded with a Statement of Feasibility by an independent certification body. This will further help to commercialise the technology.
- REDstack was rewarded as one of the three 'National Icons'. REDstack generates electricity from the salinity difference between sea- and fresh water.
- In 2016, Pentair Fairbanks Nijhuis started with the construction of their 1 MW fish-friendly bi-directional turbine in the Grevelingendam. Commissioning and grid connection are scheduled for March 2017.
- During the OTEC 2016 symposium in Amsterdam, organised by BlueRise, a Memorandum of Understanding (MoU) was signed between the Dutch Marine Energy Centre (DMEC), the Dutch Energy from Water Association (EWA) and the Ocean Energy Association of Japan. The aim is to bring Dutch marine energy innovations closer to the market.
- Early in 2016, the Bluetec floating platform was commissioned with a larger T2 Tocardo turbine.
- Huisman sold its shares in Tocardo International B.V. to the Canadian company Tribute Resources Inc.
- Tocardo has successfully tested their UFS-platform (Universal Foundation System, a U-shaped platform). Tocardo has announced that five upgraded T2 250 kW rated turbines will be installed in the Minas Passage in Canada's Bay of Fundy, late in 2017.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The Netherlands does not have a national strategy for ocean energy and nor are there specific targets. The ocean energy strategy is part of the national target of 16% renewables in 2023.
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.
For 2017, the generic national subsidy scheme (SDE, stimulating renewable energy) has also been open 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.

REGULATORY FRAMEWORK

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

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

MARKET INCENTIVES

There are no specific market incentives for ocean energy or other renewable energies. The generic DEI (Demonstration of Energy innovations) subsidy scheme supports projects with a focus on export of Dutch technology. In 2016, a few new ocean energy projects have been rewarded.

PUBLIC FUNDING PROGRAMMES

Since the 1990s, the Ministry of Economic Affairs has initiated a number of grants via generic R&D instruments; these are also available for ocean energy research.
Many projects have been supported in National funding programmes; Archimedes Wave Swing (for wave (swell) energy), Tocardo Tidal turbines, REDstack (salinity with reverse electro dialyses), BlueWater (tidal), BlueRise (OTEC), Teamwork Technology (tidal, wave) and many R&D Institutions, like ECN, NIOZ, Wetsus, Imares, Deltares, Marin, TNO and the Universities.
At the moment, two projects have been granted within the DEI (Demonstration of Energy innovations) subsidy scheme; BlueTec and Tocardo-Huisman.

RESEARCH & DEVELOPMENT

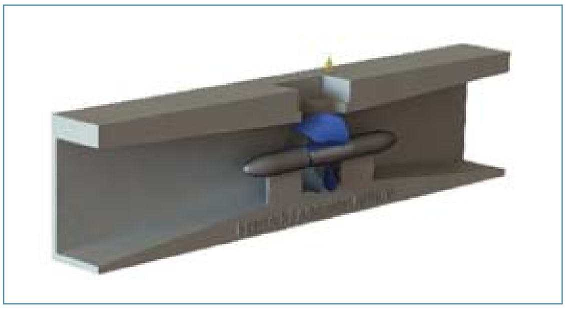
The following R&D projects have been developed during 2016:

- 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)
- Teamwork Technology (wave energy)
- Tocardo VAWT (tidal current)

TECHNOLOGY DEMONSTRATION

OPERATIONAL PROJECTS

Tocardo's 1.25 MW demonstrator in the Eastern Scheldt barrier



The 1 MW Pentair Fairbanks Nijhuis bi-directional turbine to be installed in the 'Grevelingendam'

The REDstack test facility and demonstration project at the 'Afsluitdijk'

PLANNED DEPLOYMENTS

- OTEC Pilot Curacao (500 kW)
- OTEC Pilot/Demo Martinique
- Tidal Energy Marsdiep (200 kW)
- Tidal Test Centrum Grevelingen Barrier; several techniques
- Follow up of Tocardo in Eastern Scheldt (2 MW)
- Brouwers Barrier tidal range plant (after 2018, various scenarios)
- Several arrays in Afsluitdijk discharge gates (further future)

NEW ZEALAND

CRAIG STEVENS *University of Aucklan*

INTRODUCTORY NOTE

With a population of 4.7 million people and an **Exclusive Economic Zone (EEZ)** in the global top 10 in terms of size, New Zealand/Aotearoa is essentially a maritime nation. It also has a high proportion of renewable electricity supply already but it is highly dependent on imported transport energy. There is also limited demand for energy at present.
A recent review put out a call for better investment in marine technology and engineering, especially in the tertiary education sector:

- Stevens, C., & O'Callaghan, J. (2015). When the holiday is over: being clever in New Zealand's marine domain. Journal of the Royal Society of New Zealand, 45(2), 89-94.

New Zealand has a well-developed underlying marine energy supply chain capability to support NZMEC marine energy fabrication and servicing activities. This is due to the country's longstanding experience in a variety of relevant disciplines including hydro and wind power, offshore oil & gas, marine engineering and boatbuilding. Notable elements of New Zealand's marine energy supply chain include:

- Significant marine energy research capabilities and expertise within the Universities and government-funded research agencies.
- Particular strengths arising from NZ's renewables-based power sector, offshore oil & gas industry and onshore fabrication capabilities.
- An advanced marine modelling capability, critical to the design and feasibility of project development.
- Expertise in design, implementation, automation and control systems, arising from NZ's experience in operating Cook Strait HVDC links.
- World leading capability in grid management of electricity sourced from renewable energy generation, including network embedded generation.
- The manufacture of advanced composite marine materials and structures best demonstrated by the yachts in the 2013 America's Cup.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The NZ Government has the goal of 90% renewable electricity supply by 2025. Beyond this, the Government's overarching goal is to grow New Zealand's economy and deliver greater prosperity, security and opportunities for all New Zealanders. The Government has set four key priorities in this regard, with the Government's principal economic goal, and second key priority, being to build a more competitive and productive economy:

- The 2011-2021 NZ Energy Strategy places priority on diverse resource development, with particular focus on adoption of new renewable energy technologies under which, inter alia, the Government has a role in encouraging the swift uptake of these technologies in New Zealand and supporting the deployment of home grown energy technologies domestically and overseas.
- Commercialisation and deployment of marine energy will help meet the goal of 90% renewable electricity supply by 2025.
- The Government's Foreign Investment Policy encourages permitted Greenfields investment.
- New Zealand Aid Programme Strategic Plan 2012-2015 focuses on sustainable economic development in the Pacific, and a more targeted approach in Asia with renewable energy as a key enabler.

REGULATORY FRAMEWORK

The NZ Environmental Protection Authority handles applications for marine activity offshore of the 12 nm limit under the Resource Management Act. A recent landmark case for resource exploitation went against the applicants serving notice on the high levels of certainty required around impacts (e.g. http://www.epa.govt.nz/EEZ/trans_tasman). Inshore of 12 nm exploitation applications are heard by regional authorities.

PUBLIC FUNDING PROGRAMMES

There are limited opportunities for funding specifically for marine renewable energies since the closure of the Marine Energy Deployment Fund in 2012. The energy portfolio in the Government R&D funding ministry MBIE (Ministry for Business, Innovation and Employment) has in the past funded wave energy device development projects and tidal array resource and design projects. A recent project funded by the investigator-led Marsden Fund on large array scaling and design has now come to a close (P.I. Ross Vennell, Univ. Otago).

The 2015 National Statement on Science Investment (http://www.mbie.govt.nz/info-services/science-innovation/national-statement-science-investment) laid the foundation for a number of implementing activities in 2016 including the launch of the "new" Endeavour Fund. This funding instrument would accept proposals regarding development of marine energy initiatives in a range of "mission-led" configurations. The vision for 2025 will be supported by two main pillars or areas of focus where Government will concentrate its activity. These are impact and excellence.

It is vital that all parts of the system continue to strive for greater excellence and impact in the science undertaken, with our science being of the highest quality possible and most public investment having a clear line of sight to eventual impact. A focus on impact does not mean a focus solely on close-to-market or end-user-driven research. Scientific discovery challenges, as well as supports, existing industries and practices, and both roles must be developed in a balanced way.

The new Sustainable Seas National Science Challenge (http://sustainableseaschallenge.co.nz/) aims to enhance use of New Zealand's vast marine resources, while ensuring that our marine environment is understood, cared for, and used wisely for the benefit of all, now and in the future. This requires a new way of managing the many uses of our marine resources that combines the aspirations and experience of Māori, communities, and industry with the evidence of scientific research to transform New Zealand into a world leader in sustainable marine economic development. In 2016, the Challenge launched two calls for proposals with a partial focus on Blue Economy.

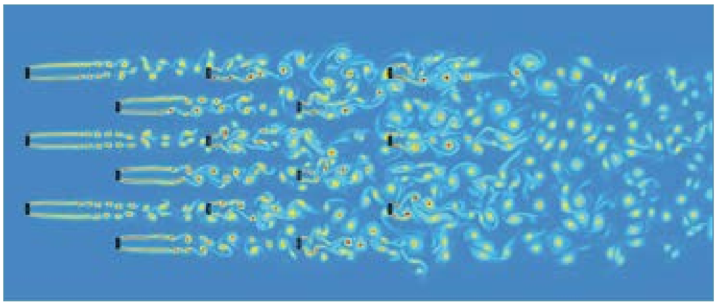
RESEARCH & DEVELOPMENT

Key R&D Institutions and Relevant R&D Projects:

- NIWA – National Institute for Water and Atmospheric Research – Government-owned environmental research agency with a focus on atmospheric and aquatic environments that operates ocean-going vessels (www.niwa.co.nz).
- HERA – Heavy Engineering Research Association (http://www.hera.org.nz/MainMenu).
- GNS - Government-owned research agency with a focus on Earth, geoscience and isotope research and consultancy services (www.gns.cri.nz).
- Univ. Otago, Department of Marine Science (http://www.otago.ac.nz/marinescience).
- WELTEC (https://www.weltec.ac.nz/).
- AUT (www.aut.ac.nz/study-at-aut/study-areas/engineering/undergraduate/maritime-majors).
- Callaghan Innovation (http://www.callaghaninnovation.govt.nz/).

The New Zealand group led by Dr Ross Vennell has made significant advances in quantifying theoretical impacts of large turbine arrays. This is enabling ideas around tuning and temporal sequencing of tuning to maximise energy extraction for minimum flow disturbance.

References:
Vennell, R., Funke, S. W., Draper, S., Stevens, C., & Divett, T. (2015). Designing large arrays of tidal turbines: A synthesis and review. Renewable and Sustainable Energy Reviews, 41, 454-472.



Flow disturbance from a modest array of turbines (Divett, Vennell and Stevens. "Optimization of multiple turbine arrays in a channel with tidally reversing flow by numerical modelling with adaptive mesh." Phil. Trans. R. Soc. A 371, no. 1985 (2013): 20120251)

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

A 2015 Business Case sought Government commitment to invest in the establishment of a marine energy testing facility, the New Zealand Marine Energy Centre ("NZMEC" or "the Centre") located in the Wellington region. The balance of investment requirements would be provided as in-kind private sector funding from a multinational firm. NZMEC's testing facilities will be located on up to four sites at Baring Head, Moa Point, Cape Terawhiti and Kapiti to provide ocean based pre-commercial scale testing services for wave and tidal energy device developers from nursery (prototype/pilot) through to full scale, grid connected devices. The JV will enable NZMEC to stand as a global centre of excellence for marine energy testing. The development is currently on hold awaiting investment.

OPERATIONAL PROJECTS

AZURA Wave – testing in Hawaii. A prototype wave generator called Azura is supplying grid power to Hawaii, the first time such a feat has been officially verified, according to the US Department of Energy (DoE). This completed a year's worth of testing in 2016.
More information at:
http://www.engadget.com/2015/07/07/wave-generator-hawaii-power-grid/

The initial technology development, called Wave Energy Technology New Zealand or WET-NZ, was conducted by Callaghan Innovation (formerly Industrial Research Limited), which is a New Zealand Crown Research Institute. Since development began in 2006, the technology has advanced from initial concept to open ocean pilot testing. Recognizing the potential of the US market, NWEI began collaborating with Callaghan to further develop and optimize the technology. Since commencing operations in 2010, NWEI and its partners have successfully completed pilot scale projects in New Zealand and Oregon, and NWEI is now preparing for a grid connected demo project at the US Navy's Wave Energy Test Site at the Marine Corps Base Hawai'i. Unlike other wave energy technologies, Azura extracts energy from both the heave (vertical) and surge (horizontal) motion of the wave, producing power from the relative rotational motion between the hull and float. The Power Take Off (PTO) system is based on high pressure hydraulics and is located within the PowerPod.

http://azurawave.com/wave-generator-supplies-us-electrical-grid-for-the-first-time/

OTHER RELEVANT NATIONAL ACTIVITIES

The national marine energy advocacy group AWATEA (Aotearoa wave and tidal energy association) runs an annual meeting with international attendance. It was established in April 2006 to advocate for, assist and accelerate the development of the marine energy industry. It acts as an industry association with the following mission: "AWATEA will promote, aid and foster a vibrant and viable marine energy industry in New Zealand". The association has the following objectives:

- Promote the marine energy industry in New Zealand, including research, energy generation, marine fabrication and marine services;
- Increase recognition and utilization of marine energy as another energy source in New Zealand's supply portfolio;
- Act as a centre for advocacy of marine energy, including lobbying, drawing up submissions to Government and representing the views of the marine energy industry;
- Exchange information about the marine energy sector, to provide and publish statistics and informed commentary on issues affecting the uptake of marine energy in New Zealand;
- Be a meeting place for marine energy industry participants;
- Represent the New Zealand marine energy industry to national bodies, including Government agencies, non-governmental organizations and other industry bodies and liaise with other international bodies.

It ran its 10th annual conference in May 2016:
http://www.awatea.org.nz/uncategorized/programme-released/

This group produced a 2016 whitepaper which is currently being updated:
http://www.awatea.org.nz/information/white-paper/

NORWAY

DANIEL WILLOCH, *Norwea* HARALD RIKHEIM, *Research Council of Norway*

INTRODUCTORY NOTE

This year in Norway, we have seen the deployment of two prototypes. Deep River tested a 250 kW pilot in May, and the Tide Tec scaled prototype was deployed in Svelvik outside Drammen, in the southeast. Wave power was mentioned in the white paper on energy policy (Meld. St. 25 2015-2016) published by the Government this year. In that short mention, the Government concedes that there is interest in testing wave power technology on the Norwegian coast.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

Norway has no special policy for ocean energy, but ocean energy is included in more general renewable energy policies and programmes.

REGULATORY FRAMEWORK

The Ocean Energy Bill, which regulates offshore renewable energy production entered into force on 1 July 2010. According to this new legislation, licences 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. This legal framework is very much inspired by similar legislation in the Norwegian petroleum sector.

As a follow up to the Ocean Energy Bill, a group of relevant governmental bodies has identified 15 areas that could be suitable for large scale offshore wind power. More detailed "strategic consequence assessments" were finalized in 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. No strategy for the realization of Norwegian demonstrators of floating offshore wind power and other forms of offshore renewable energy production has been presented by the Government, even though Parliament called for such a strategy to be presented in the white paper.

MARKET INCENTIVES

Norway and Sweden have been in a joint green certificate market, since 2011. Since 2012, one certificate per MWh has be given to all new renewable energy generation for 15 years, independent of technology. From year 2022, Norway will no longer participate in the scheme, while Sweden will increase their target build-out under the scheme with 18 TWh by 2030.

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

The research cluster in Trondheim, comprising NTNU and SINTEF/MARINTEK, is active in ocean energy research. Some of the activities are: technology screening and verification, control systems, mooring, marine structures, safety, optimal design of devices and load modelling. MARINTEK's model tank is also used to test ocean energy devices. SINTEF/NTNU is a member of the EU MARINET research network.

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. Among the renewable energy projects tested has been wave energy converters, wind turbine installation concepts, wind turbine foundation solutions and wind turbine service vessels.

Tide Tec AS, a Norway-based hydropower technology company, have displayed and tested the new and innovative turbine turning mechanism prototype in Svelvik, Norway, between August and November 2016. The prototype is intended to simulate a large-scale barrage or lagoon application for a low head hydro turbine. The turret has been tested for 6 weeks in a tidal stream environment. "The seawater tests give us proof of concept and show that a turning classic low head hydro turbine can be the most efficient tidal lagoon or barrage turbine", says Joachim N. Amland, CTO at Tide Tec. From late August, the prototype has been submerged for a test period of 6 weeks. "The testing show the robustness of the turning mechanism and the ability to keep the intended areas dry. In addition, we tested that the turret proves as a robust housing for a low head hydro turbine. The next steps will be to integrate a suited turbine into our turret, and upscale the technology", says Joachim N. Amland.

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

Runde Environmental Centre (REC), located on Runde Island on the Norwegian west coast (http://www.runde-centre.no), can accommodate wave energy projects for test and demonstration at several sites. The site 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 also 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 OE devices in the area. The same applies to the wave forecasting model installed in co-operation with the Norwegian Met office.

The Swedish developer Waves4power (www.waves4power.com) deployed their WavEl floating wave energy device by an offshore vessel in February, 2016. Held by three anchors, it survived the stormy period before the summer. Now being subject to upgrades, the plant will be re-deployed before the end of 2016.

OPERATIONAL PROJECTS

Havkraft AS is a Norwegian technology company specialized in wave energy conversion. The company finalized their prototype testing of the Havkraft Wave Energy Converter (H-WEC) in real sea environment at Stad in Sogn og Fjordane, Norway, in 2015 with ground breaking results. With over 4500 controlled running hours with power production, surviving direct exposed hurricanes and documenting a "cut-in speed" on the converters at 2 kW/m, the patented technology has proven its ability to produce energy in a very broad spectrum of frequencies. The current stage is to implement the wave energy converters into offshore aquaculture, offshore wind installations and other applications worldwide. The company is headed by inventor Geir Arne Solheim, in close team with a range of highly skilled partners.

PLANNED DEPLOYMENTS

Deep River has developed a mobile «plug and go» power plant which utilises the kinetic energy in rivers as well as tidal and ocean currents. A 250 kW pilot was tested in May 2016. The Deep River concept is turbine and generator on standard, container or pallet based solutions. Standardizing dimensions eases both transport and installation. The power plants are fully scalable, both in number and size of turbines. The power plants may be built with a number of different anchoring solutions, and is deliverable with buoyancy tanks.
Deep River has also developed 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.

The Deep River prototype under testing in May 2016

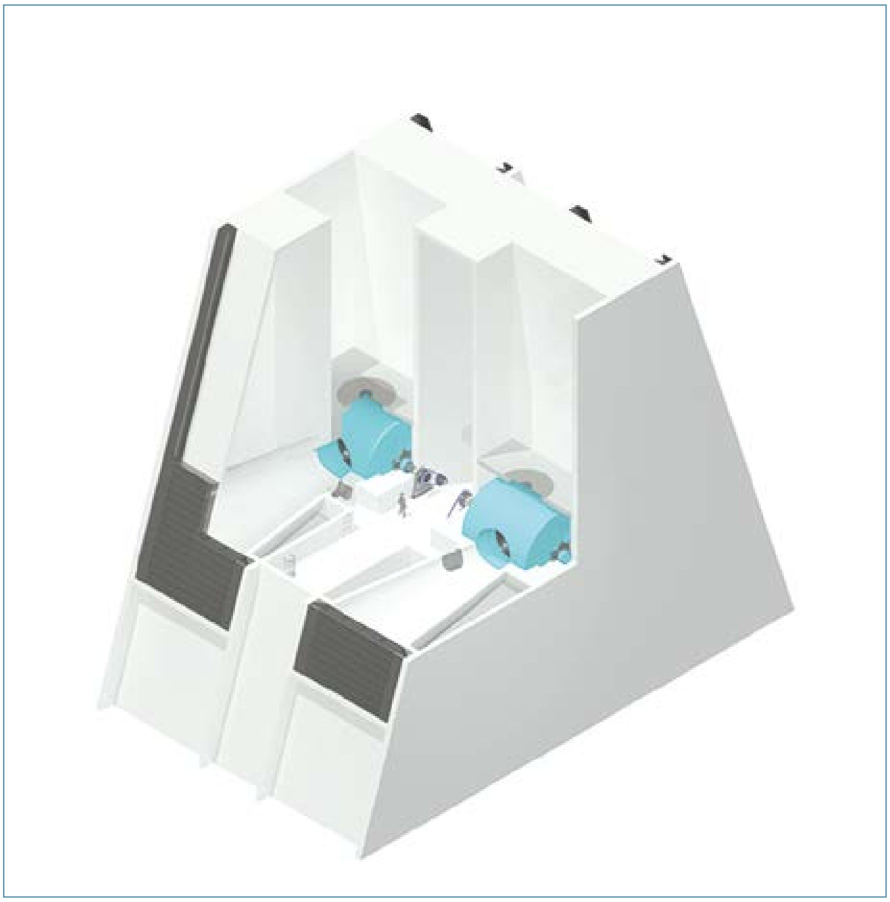
Tidal Sails AS, an independent, privately held closed corporation based in Haugesund, Norway, develops a ground breaking technology to extract kinetic energy from slow moving water by combining the ancient principles of ocean sailing with state of the art alpine ropeway technology. Linearly moving sails have great extraction efficiency, thus dramatically reducing the cost of the electricity generation. Tidal Sails technology can be adapted to most river, ocean and tidal current locations, and is protected by several patents worldwide.

Ocean Energy AS has designed a worldwide patented wave energy plant. The technology is based on the Swedish wave company Seabased AB, but Ocean Energy has developed and patented a "Storm Buoy". The Storm Buoy can be submerged and withstand extreme waves. The solution is developed in cooperation with universities in Norway (NTNU), as well as the "Maritime Cluster" at Ulsteinvik, Sunnmøre in Western Norway. The project is supported by Innovation Norway and Ocean Energy plans to install a demonstration at Runde (www.ocean-energy.no).

Flumill is planning to deploy its first commercial scale grid connected demonstration system at the marine test centre EMEC, in the UK. The system will be rated at 2 MW and produce up to 5 MW tidal energy at the EMEC location on Orkney Islands. The system will be deployed in 2017.

Andritz Hydro Hammerfest was founded in Norway in 1997 by the local utility company Hammerfest Energy and is currently owned by Andritz Hydro and Iberdrola. Andritz Hydro Hammerfest is among the leading tidal energy technology developers in the world and is now taking the step into commercial delivery: Andritz Hydro Hammerfest is currently developing and producing three MK1 turbines (1.5 MW) for installation at the MeyGen project in Pentland Firth.

Tide Tec consists of a turret or turning mechanism, intended to house a hydro turbine. The turbine can be turned 180 degrees to get optimal efficiency of a hydro turbine in a tidal power plant. Most tidal power plants today generate power only in one direction. Projected plants with two-way production have sub-optimal production when the water flows "backwards" into the turbine. The solution is aimed at the tidal range market with tidal barrages and lagoons. It can also be used for active flood protection applications, or integration into existing flood protection infrastructure, such as dikes. To show the feasibility of the Tide Tec system they are currently developing a model turbine together with TUM (Technical University in Munich).
Tide Tec are planning a new fundraising in the beginning of 2017 to fund engineering of a bigger scale pilot and further prove that the Tide Tec turret can house a 20 MW turbine with a runner diameter of 7.5 meters. In October Tide Tec tendered together with Aibel for prequalification for the Churchill Barrier Project on Orkney Island.



The Tidetec system

PORTUGAL

ANA BRITO E MELO *WavEC* ANTÓNIO FALCÃO *Instituto Superior Técnico*

INTRODUCTORY NOTE

Last year, the Portuguese Government mentioned their intention to attract more national and international investment for the economy of the sea, recognizing the need to support the development of new technological platforms linked to research, innovation, science and technology, related to maritime sectors, including oceanic renewable energies. AW-Energy submitted the licensing application for their 5.6 MW NER300 winning SWELL project; the Australian developer Bombora Wave Power is taking the first steps towards the development of a prototype planned to be tested in Portugal.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The National Ocean Strategy 2013-2020 is the public policy instrument in Portugal for the sustainable development of the economic sectors related to the ocean, including the energy sector. The three key pillars of the maritime economy are: Knowledge, Spatial Planning, and Promotion of National Interests. It is available at:
http://www.dgpm.mam.gov.pt/Documents/ENM_Final_EN_V2.pdf

During 2016, the Government established an Inter-Ministerial Commission for Maritime Affairs (CIAM) and created an inter-ministerial Working Group, called 'Energy at Sea', with the mission of discussing a "development model that ensures the rationalization of the means used to develop offshore electricity", aiming at "enhancing investment in R&D, including technological demonstration projects and pre-commercial projects in this area." This group prepared the report "*Energy at Sea - Roadmap to an Industrial Strategy for Oceanic Renewable Energies*" which includes a set of recommendations for attracting investment in this area. It concludes that there is a clear opportunity to attract projects to Portugal, highlighting that the realization of these projects in Portugal and the creation of value around them should be a priority of the Working Group on Marine Renewable Energy.
The report (Portuguese version) is public available at:
https://www.dgrm.mm.gov.pt/xportal/xmain?xpid=dgrm&xpgid=genericPageV2&conteudoDetalhe_v2=6337667

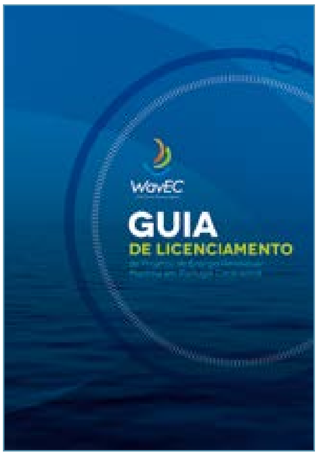
REGULATORY FRAMEWORK

In March 2015, the Portuguese Law no. 38/2015 was created, laying down the bases of the Planning and Management of the National Maritime Space (LBOGEM), defining the legal framework that allows for the implementation of marine spatial plans in the whole national maritime space, including the continental shelf beyond 200 nautical miles.

Ocean energy projects in Portugal require the following licenses:

- License for water resources utilization – managed by the Portuguese Environmental Agency (APA). This license is the main consent required and can be authorized through a license or concession:
    - A license is required for devices deployed for less than one year and for installed capacity below or equal to 25 MW;
    - A concession is mandatory for more lengthy time periods. In this case, a competitive public examination must be carried out, starting with a public announcement by the competent authority.

- Environmental license – managed by the Coordination Committee on Regional Development (CCDR) which is the regional authority;
- License for the power production or grid connection – a request made by the developer to the Portuguese Electricity Distribution (EDP);
- Building license for infrastructure on land (e.g. substation, cable routes) administered by the municipal council of the area where the project is to be installed.



In June 2016, WavEC organized a workshop to present the Licensing Guide for Marine Renewable Energies in Portugal to a group of public entities. This Guide has been partially funded by H2020 RICORE project. The final version (in Portuguese) has been launched on WavEC's annual seminar in October and is available at: http://www.wavec.org/content/files/Guia_Wavec_web.pdf
The English version will be available in 2017.

PUBLIC FUNDING PROGRAMMES

FCT (The Foundation for Science & Technology) is the main funding agency providing support for research projects and also for advanced training, mainly at the PhD and postdoc levels. FCT is part of OCEANERA-NET, a network of 16 European national and regional funders and managers of research and innovation programmes, from 9 countries, in the field of ocean energy, funded by the European Commission.
In parallel, the Agência Nacional de Inovação (ANI), has also a role in funding applied research and innovation activities. ANI is more oriented to stimulate business-oriented research in Portugal. The main sources of the funds managed by ANI are the Operational Programmes.
The Operational Programme of the national strategic reference framework 2014-2020, known as Portugal 2020, is the main instrument for business investment, defining the financing priorities in the application of the European Structural and Investment Funds in Portugal. It is comprised of four thematic Operational Programmes and seven regional Operational Programmes directly addressed to the promotion of research and innovation in the regions concerned. In particular, 2 topics can address marine energy technology: competitiveness and internationalization through **COMPETE 2020** Programme and sustainability and efficient use of resources through **POSEUR** Programme.

RESEARCH & DEVELOPMENT

WavEC

WavEC is a private non-profit association, currently with 11 associates (industrial 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.
In 2016, WavEC coordinated two European funded projects (WETFEET and OCEANET) and was further strongly involved in a number of R&D projects mainly funded by the European Commission and by the national Foundation for Science and Technology (FCT), through the Oceanera-net funding programme.

The following table lists the R&D projects addressing ocean energy conducted by WavEC:

PROJECT	FUNDING	DURATION	TOPIC
PolyWec	European Commission FP7	2012 – 2016	Application of electro-active polymers in wave energy systems
DTOcean	European Commission FP7	2013 - 2016	Open-source numerical tools for design and planning of wave energy arrays
Hiwave	KIC-Innoenergy	2013 – 2016	Development of the wave energy device of the Swedish developer, CorPower
Oceanet	European Commission FP7	2013 – 2017	Training network in wave and offshore wind
Fortissimo	European Commission FP7	2015 – 2016	Numerical modelling tools
Merika	European Commission FP7	2014 – 2018	Training programme on environmental issues related with marine energy
WetFeet	European Commission H2020	2015 – 2018	Innovative wave energy concepts
Ricore	European Commission H2020	2015 – 2017	Licencing procedures for marine energy technologies
Waveboost	European Commission H2020	2016 – 2019	Improvement of the reliability and performance of PTOs in collaboration with the Swedish developer, Corpower.
Oceanic	Oceanera-NET	2015 – 2018	Test of anti-corrosion protections for devices in the sea
Recode	Oceanera-NET	2015 – 2018	Development of electrical components for monitoring and control
Tupperwave	Oceanera-NET	2015 – 2017	Development of an OWC system

In September 2016, a public session was organised in Portugal by the Swedish developer Corpower Ocean AB in collaboration with WavEC and the Portuguese start-up Composite Solutions, to present Corpower's wave energy prototype. The device was built in Portugal by Composite Solutions with 11 m long and 4 m in diameter, and transported to Sweden to be then tested in Scotland. This development was undertaken within the European funded project HiWave - "High Efficiency Wave Power" – concluded in 2016, led by Corpower, with Iberdrola and WavEC as partners. WaveBoost is the new three-year Horizon 2020 funded project approved in 2016 aiming to develop and validate an innovative Power Take-Off (PTO) technology. This project will be conducted by an European consortium including Corpower, EDP, WavEC, EMEC, the SP Technical Research Institute, PMC Cylinders, the University of Edinburgh and GS-Hydro.

Corpower wave energy prototype build in Portugal (http://composite-solutions.pt/en/category/press/)

Under the scope of the OCEANIC project, WavEC has deployed in August 2016 an experimental structure to test different coating techniques. The structure was designed and assembled in WavEC premises and was installed in the WaveRoller test site location.

The 18 months H2020 project RICORE ended in 2016 with a public event during EUSEW 2016 (European Union Sustainable Energy Week). More information about RICORE is available on the project website (http://ricore-project.eu/).

In the scope of the four-year Marie Curie funded OCEANET project two workshops took place in 2016, one in Sweden (*Environmental impact & monitoring of offshore renewable energy farms*) and a second one in Ireland (*Social and economic impacts of offshore renewable energy*). WavEC lectured the environment and economic modules in both courses, respectively.

The Atlantic Power Cluster project was one of the five winners of the Atlantic Project Award in September 2016. The Atlantic Project Awards ceremony was held during the 3rd Atlantic Stakeholder Platform Conference in Dublin on September 27, 2016. These awards were designed to honour outstanding success stories, achieved by projects in the geographical area covered by the Atlantic Strategy and related to the implementation of the Atlantic Action Plan. WavEC took a relevant participation in this EU funded project that aimed to apply a marine renewable transnational strategy in the Atlantic area.

Another three R&D projects were approved in late 2016 to start in 2017:

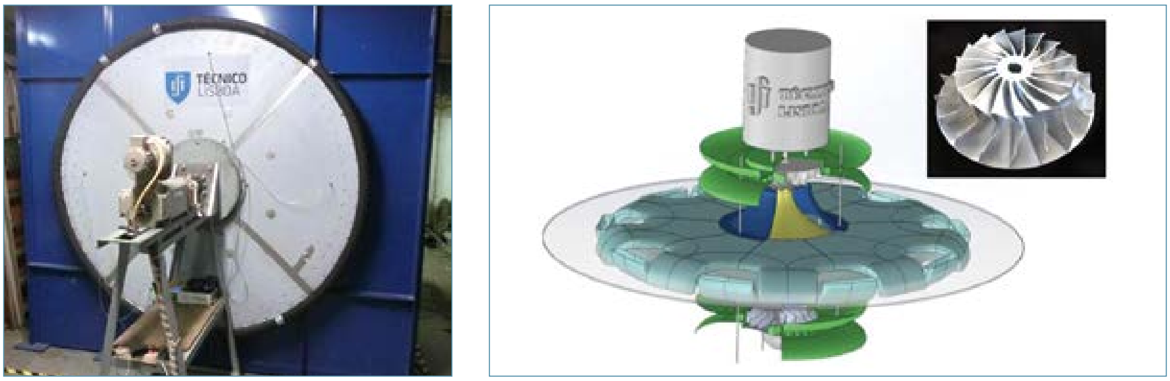
- MARINET2: a network of testing infrastructures for wave and tidal energy, giving easy access conditions to developers.
- MARINERG-I: aiming to become the leading internationally distributed infrastructure in the Marine Renewable Energy sector.
- ERAKRAKEN: aiming to tackle the existing gap of the ROV tools specially designed for the Ocean Energy sector needs with the objective to reduce the high OPEX costs associated to the underwater inspection repair and maintenance.

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 the new types of air turbines fitted with fast valves.



Model testing of the biradial turbine at IST (left); twin-rotor radial-inflow turbine (right).

IDMEC/IST is a partner in the WETFEET project (European H2020 programme); their involvement concerns mainly the experimental development of a high-efficiency twin-rotor radial-inflow self-rectifying air turbine. IDMEC/IST is also a partner in the OPERA project (H2020), in which they are developing the biradial self-rectifying air turbine with a new type of fixed guide vanes. Model testing took place at IST in 2016. Also within the framework of the OPERA project, a prototype of the biradial turbine was designed jointly by IDMEC/IST and the Portuguese company Kymaner, and is being constructed to be field-tested in 2017, firstly at one of the OWCs of the Mutriku breakwater (Basque Country, Spain) and subsequently, also in the Bay of Biscay, on the spar-buoy OWC of the Spanish company Oceantec.

Ocean energy is a major area in the diversified activity of CENTEC/IST. The activities at CENTEC in ocean energy involved a wide range of topics covering waves, tidal currents and offshore wind. The characterization of the wave energy resource (and to a much lesser extent tidal and offshore wind energies) at various oceanic locations in the world has been one of the dominant topics. The study of ocean energy conversion focused mainly on wave energy converters, with numerical theoretical/modelling of several types of devices and arrays, and also PTOs (namely hydraulic-circuit PTOs).

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

In 2016 a discussion was initiated towards moving the localisation of the Portuguese Pilot zone from São Pedro de Moel to Póvoa de Varzim, where the Offshore wind prototype Windfloat has been tested for 3 years. In this area two wave energy projects were tested in the past, the AWS in 2004 and Pelamis in 2006. The underwater electrical cable has been always the same, installed since the first wave energy tests in that site.

OPERATIONAL PROJECTS

In 2016, only one project on wave energy was running in Portugal, Pico Plant on the Island of Pico, Azores. 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, and operated by WavEC. In 2016 the plant produced 39 MWh.

It has been decided to decommission the plant, which has achieved 10 years of continuous operation, with interruptions for maintenance and replacement of components. During this period, Pico plant has allowed to develop and test maintenance methodologies, as well as to validate numerical simulation codes, further providing training for several researchers, including PhD studies.

PLANNED DEPLOYMENTS

WaveRoller

During year, AW-Energy provided two major milestones for the whole emerging industry as in June Lloyd's Register awarded its first ever Technology Qualification certificate in the domain of ocean energy to WaveRoller technology. Another significant milestone was the €10 million financing contract secured from the European Investment Bank, taking ocean energy among the industries financed by the bank. Both milestones are major steps towards commercial bankability of the ocean energy technologies.

In Portugal, AW-Energy is currently working with its partners and customers in three different projects. Delivery of the first commercial 350 kW rated machine is at finalization phase and the unit is rolling out from the assembly line during the spring time 2017. In addition to this project, the company is currently working with an industrial consortium looking to install three more 350 kW units during 2018-2019, and the licensing of the 5.6MW NER300 winning SWELL project has been planned to start during 2017.

Bombora Wave Power

The Australian company, Bombora Wave Power, is planning its first real scale deployment in Europe and is considering to undertake the project in Peniche. The company has been preparing the documentation to apply for the licensing process in Portugal and is now looking for potential partners.

OTHER RELEVANT NATIONAL ACTIVITIES

2nd International Conference on Renewable Energies Offshore

CENTEC/IST organized the 2nd International Conference on Renewable Energies Offshore, which took place in Lisbon on 24-26 October 2016. 103 papers where presented. The proceedings were published by CRC Press.

WavEC Annual Seminar

WavEC, the Embassy of Finland in Lisbon, Machine Technology Centre Turku, Tekes - the Finnish Funding Agency for Innovation and the Ministry of Economic Affairs and Employment of Finland, organised together a seminar on marine renewable energies on the 26th October 2016. The event had 212 participants and counted with the presence of the Portuguese Minister of Sea. The seminar focused on the following four topics:

- Synergies between different blue growth activities and enabling technologies at the sea;
- Company cases on marine renewable energies solutions;
- The future of marine renewable energies;
- Blue collaboration between Portugal and Finland.

Presentations are available at WavEC's website: http://www.wavec.org/en/events/wavec_seminar_2016

Further, a B2B event on marine renewable energies was held in Lisbon on 27th October organised in partnership between WavEC and the Embassy of Finland in Lisbon.

EUREC master course

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 2016.

REPUBLIC OF KOREA

KEYYONG HONG *Korea Research Institute of Ships and Ocean engineering*

INTRODUCTORY NOTE

Development of ocean energy in Korea has been predominantly focused on establishing promotions for commercialization and technology demonstrations. In 2016, this industrial trend began to move forward by launching new projects, which involve construction and demonstration of open sea test sites and ocean energy systems. The market incentive for renewables in Korea is based on the Renewable Energy Certificate (REC) policy. A REC value for tidal current is currently 2.0 and they consider its increase to accelerate the market development. In addition, the inclusion of wave and ocean thermal energies in REC policy is presently being discussed.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The national strategy for the development of ocean energy 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.

REGULATORY FRAMEWORK

Although there is no explicit legislation or regulation related to ocean energy by itself, there are national acts towards the development of the renewable energy, such as the "Framework Act on Low Carbon, Green Growth", the "Act on the Promotion of the Development, Use and Diffusion of New and Renewable Energy", and the "Energy Act" in general. Furthermore, various regulatory measures for marine environmental protection are being implemented in the development of ocean energy, such as the "Framework Act on Marine Fishery Development" and the "Marine Environment Management Act".

The "Act on the Promotion of the Development, Use and Diffusion of New and Renewable Energy" enforces the obligatory appliance of the renewable energy resources for public buildings and the thermal ocean energy for the air conditioning is to be one of the renewable energy resources.

MARKET INCENTIVES

The renewable portfolio standard 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 value of REC is 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.

PUBLIC FUNDING PROGRAMMES

MOF and MOTIE provide public funding for ocean energy R&D, as well as demonstration projects. 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

10 MW Class Wave-Offshore Wind Hybrid Power Generation System

The main objective of this project was to develop the design technology for the 10 MW wave offshore wind hybrid power generation system and to design the 10 MW standard model powered by the deep ocean energy resource. The project, with the duration of approximately 3 years, from June 2013 to May 2016, was supported by the Korean Government, through the Ministry of Oceans and Fisheries, with USD 11 million for the total amount of funding. The project team was organised and led by KRISO and 10 universities (8 Domestic and 2 International), 5 research institutes (4 Domestic and 1 International), and 10 industrial companies (8 Domestic and 2 International). The major research contents for the project were as follows:

- Development of design technology for a floating wave-offshore wind hybrid power generation system;
- Development of structural safety analysis and high strength material application technology for a large floating wave-offshore wind hybrid power structure;
- Development of integrated control and grid connection technology for wave-offshore wind hybrid power generation system;
- Development of design standardization and practical application technology for a wave-offshore wind hybrid power generation system;
- As a result, the project has succeeded to develop the design of a floating wave-offshore wind hybrid power generation system, as well as the performance analysing programme with the design manuals for the floating wave-offshore wind power generation system.

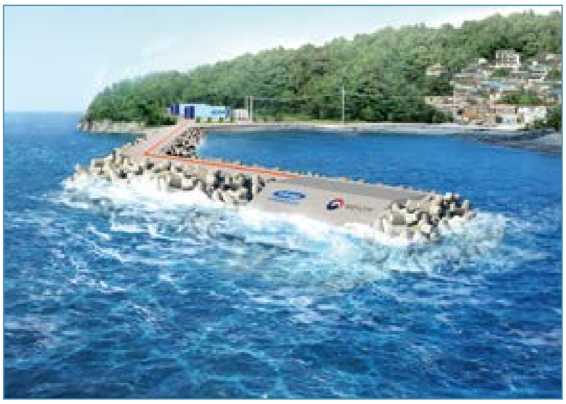
Wave Energy Converter with Energy Storage System Applicable to Breakwaters in Remote Island

The present research project is aimed to establish the commercializing foundation for the ocean energy by developing the integrated energy storage system and wave energy converters, applicable to the breakwater in remote harbours and ports. The project, with the duration of approximately 4 years, from May 2016 to December 2020, is supported by the Korean Government, through the Ministry of Oceans and Fisheries. The major research contents for the project are as follows:

- Prioritization of potential sites for the wave power generation, and detail survey and analysis on their environmental conditions;
- Development of a standard model of small capacity wave energy converters (WECs) applicable to the breakwater;
- Development of interface technologies of an integrated system of wave power converters and energy storage system (ESS), useful for remote islands with independent micro grid network;
- Sea test of a pilot plant of the integrated system of WECs applied to the breakwater and ESS embedded to the independent micro grid system.

In 2016, the basic survey for potential sites and determination of the pilot plant location for WECs was carried out, as well as the conceptual design of the small WEC system, applicable to the breakwater, and the micro grid system with the independent source of WECs.

10 MW wave-offshore wind hybrid system



WEC applicable to breakwaters in remote island

Arrayed Buoy Wave Energy Converter Adaptive to Wave Climate

The research and development project for the 1 MW arrayed-buoy wave energy converter, started in December 2016 with four years of project duration, is aimed at developing the basic design of an arrayed-buoy, the floating platform, and the swivel power cable system. The system will consist of the floating platform, the weather vanning mooring system, the Salter's duck type wave energy converters, and the hydraulic power take-off system. Furthermore, the system will be equipped with the motion suppression mechanism to maximise the generated power from the array-buoy. The project is expected to be ended by 2020 after the sea trial near the Jeju Island.

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

MOF has been supporting construction projects of the open sea test bed for wave energy converters and tidal energy converters, respectively. The construction project 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 and utilized as the offshore substation. 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. 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 2017.

The construction project for the tidal wave energy converter, started at the end of 2016, is planning to build the open sea test bed with 5 berths of 4.5 MW grid-connected capacity, from May 2017 to December 2021. Furthermore, the performance test facility for components of tidal energy converters, such as blade and drive train, will be constructed in the project.

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.

INWave Onshore-Based WEC Plant

INWave™, developed by INGINE, is the onshore-based WEC whose key equipment is installed on land and the energy-absorbing unit is placed on water in close proximity to shoreline. This system holds economic feasibility as it does not require the undersea cable even in a small scale. Furthermore, it maximises the efficiency in shallow waters, by collecting the wave energy from multiple directions. Since the installation of its first 135 KW pilot plant on Jeju Island in late 2015, the plant has been in operation, connected to the power grid.

500 kW Yongsoo OWC plant

NWave onshore-based WEC plant

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, SUPRC, in Gangwon-do Goseoung-gun, a subsidiary research centre of KRISO dedicated to the deep-sea water 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 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 500Kw woodchip gasification plant for 200 kW HOTEC plant

Heaving Semi-Spheres with Hinged Arm WEC Platform (Hwa Jin Co.)

The "30KW Heaving Semi-spheres with Hinged Arm WEC Platform" project was successfully concluded in 2016. This project has been developed by Hwa Jin Co. and funded by MOTIE. The project aimed to undertake a device development of a Jack-up type WEC platform with Hydraulic PTO system. The prototype has installed near Hupo-hang in the East Sea.

Offshore 1 MW OTEC

Heaving semi-sphere WEC with hinged arm

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 (>20 m/s). The TEC was manufactured and its substructure was deployed by KIOST and HDEC in 2016. The remaining part of TEC is planned to be deployed in 2017 followed by performance demonstration of TEC between 2017 and 2018.

200 kW active-controlled tidal energy converter in fabrication and installation of its substructure

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. The FPWEC is planned to be tested at the open sea WEC test centre of Jeju in 2018.

Construction of 300 kW floating pendulum WEC

SUPRC 1MW 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 construction and perform the short-term operation in the east coast of South Korea by 2018, followed by transferring and conducting long-term operation in Tarawa, Kiribati, in 2019. In 2016, KRISO manufactured the 1.2 MW turbine generator, and investigated the external environmental force of the plant site in 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 marine 1 MW OTEC plant and the AIP for the 10 MW OTEC plant.

SINGAPORE

DR. NARASIMALU SRIKANTH, MR. MAHESH RAMANATHAN S, MS. MARY ANN JOY QUIRAPAS AND DR. MICHAEL ABUNDO
Energy Research Institute @ Nanyang Technological University (ERI@N)

INTRODUCTORY NOTE

Singapore has significant interest in renewable energy RD&D. Noteworthy milestones in Singapore's Ocean Renewable Energy (ORE) activities include the development of various marine renewable energy test bedding sites, and collaborative projects between academic research institutes and industry, all of which benefit from the support of public agencies.

The Renewable Energy Integration Demonstrator Singapore (REIDS) project aims to test and demonstrate, in a large scale, micro grid setting on Pulau Semakau Island, the integration of a broad range of onshore and offshore renewable energy production, energy storage and energy management technologies. The REIDS project, led by the Nanyang Technological University (NTU) and supported by the Singapore Economic Development Board (EDB) and the National Environment Agency (NEA), was officially launched in October 2014 with ten industry partners.

At the regional level, the Southeast Asian Collaboration for Ocean Renewable Energy (SEAcORE) was initiated by ERI@N with partners from Southeast Asia to promote renewables and create new markets for partner industrial firms (ERI@N Report, 2012-2014). The Asian Centre for Energy (ACE) has recognized ERI@N's efforts in creating the SEAcORE network, making it its official technical working group on ORE in the Southeast Asia region. Techno-economic feasibility projects between Singapore and other Southeast Asian countries, including Indonesia and the Philippines, are currently on-going through the SEAcORE platform. In 2016, ERI@N organized the Asian Wave and Tidal Energy Conference as part of Singapore Energy Week (SIEW 2016), where more than 350 participants from Asia, Europe and North America of varied backgrounds, including academia, industries and policy makers related to ocean energy systems benefited from this event.

2016 was seen as a successful year with completion of different marine-related projects and a stronger regional commitment towards more innovative and effective means of fully utilising ocean energy sources and technology towards tropical remote regional needs.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

Singapore is determined to reach its national targets to become economically greener and provide environmental and sustainable development for the whole city-state. Singapore has recently announced that "it intends to reduce its emissions intensity by 36% from 2005 levels by 2030, and stabilise its emissions with the aim of peaking around 2030" (UNFCCC, 2015). This makes the country more determined to establish different energy efficiency measures and to harness alternative sources of energy. The Government sees renewable energy as an emerging field, which needs to be closely studied and developed in tune to regional needs (SMI, 2014).

More than S$800 million public funding has been set aside by the Singapore Government for research in energy, water, green buildings and addressing land scarcity, of which S$140 million is allocated for research into clean energy technologies under the banner of the Energy Innovation Programme Office (EIPO) (EDB, 2015). Ocean renewable energy has been identified as one of the prominent alternative energy by ERI@N specifically towards remote coastal and islandic region as part of its strategic research interests.

Singapore, being a small city-state, yet develops its own solutions to address constraints in land and water resources by building partnerships between public agencies, academia and industries towards the country's sustainability agenda.

An example of this is Singapore positioning itself as a "Living Laboratory" – "making its national urban infrastructure available to local and international companies who find it useful to develop, test, prove and showcase their solutions in a real-life urban environment that is also representative of many Asian cities" (EDB, 2015). This enables Singapore to harness the best technologies and industrial solutions from its partners.

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.

The W&M key research, development, and demonstration efforts of the team include the following:
1) Tidal, wind and wave energy resource assessment towards Singapore and other regions of South East Asia;
2) Test-bedding activities of marine renewables (e.g. Sentosa Tidal Test Site and Tanah Merah Wave Energy Test Site);
3) Renewable Energy Integration Demonstrator-Singapore (REIDS) – Offshore;
4) Advanced materials and coatings development towards tropical needs and
5) Regional and international collaborative projects related to resource mapping and test-bedding of ocean energy systems.

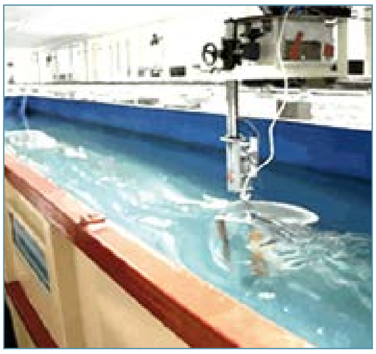
Renewable Energy Integration Demonstrator-Singapore (REIDS)
REIDS aims to power Pulau Semakau, an island south of mainland Singapore, which serves as a landfill, purely through renewables, including ocean energy. First of its kind in the region, the hybrid micro grid will facilitate the development and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

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

REIDS Offshore: **Environmental Impact assessment activity in Singapore:** The offshore renewable energy integration and demonstration (Offshore REIDS) project, also termed as Tropical Marine Energy Centre (TMEC), has been initiated by ERI@N and financially funded by the ClassNK firm (a Japanese classification society) and seeks to pave the way for establishing the world's first scaled marine renewable energy testing facility for tropical needs. In March 2015, the feasibility study for the test sites was officially launched and is expected to be completed by December 2017. During this project, the resource mapping methodologies are well utilized to identify the ocean energy potential of the southern islands of Singapore that have been identified from the Maritime port Authority of Singapore (MPA). Presently, an environmental impact assessment (EIA) for the test sites is being carried out to understand the impact of ocean energy system deployment on marine life and environment. The EIA includes investigating the baseline conditions, possible effects of the test sites in the surroundings, and other associated research, such as underwater acoustics, water purity, sea level changes, tidal flow effects, etc. Geotechnical and geophysical surveys are also being planned. The outcome of this project will be extended towards Singapore's guidelines and standards development by working with Spring Singapore to support local supply chain's marine energy resource mapping guidelines of new regions, such as our neighbouring region of Southeast Asia and other tropical islands and remote coastal regions. Overall, the present project aims to develop technologies and deployment methodology for meeting energy needs towards the remote island region.

GOVERNMENT FUNDED R&D

Flexible Distributed Generation using tidal in-stream energy system for remote island applications:
Among the government funded projects is the "DG-TISE: Flexible Distributed Generation using tidal in-stream energy system for remote island applications". This research grant aims to develop energy generation and micro grid systems for research work in the country (EDB, 2014). DG-TISE aims to develop "a novel sensing and signal analysis system which will provide a tidal energy resource measurement method to account for the geographical sea bed conditions and tidal current measurements", and to evaluate and test bed a commercially ready turbine in Singapore waters. Research outcomes show promising turbine rotor designs that are efficient in low tidal flow conditions and robust towards environmental challenges, such as seaweed entanglement and biofouling resistance.
Sentosa-ERI@N Tidal Test Site


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

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 display 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).

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. Figure 2 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, 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.
This project is one of the pioneering tidal turbine deployment in Southeast Asia and may act as a model for smaller scale

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

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.

OTHER RELEVANT NATIONAL ACTIVITIES

Technical Training Workshop on Ocean Renewables

As part of continuous efforts to increase the capabilities of ocean renewable energy stakeholders in the region, ERI@N together with Sustainable Energy Association of Singapore (SEAS) and Ocean pixel Pte. Ltd., has organized a training workshop on Ocean Renewable Energy for new entrants in the Southeast Asian marine and offshore energy market. This workshop was held as part of the pre-conference events of the Asian Wave and Tidal Energy Conference (AWTEC 2016). ERI@N closely worked with the two partners as its technical lead on identifying the right topics and ocean energy experts to speak during the three-day workshop. The workshop was well attended by local small to medium enterprises (SMEs) in marine/offshore industry with interest in expanding their capabilities to ocean renewable energy. In addition, there were also participants from different Southeast Asian countries who are mostly the experts or currently doing the ocean renewable energy activities in their respective countries.

ASIAN WAVE AND TIDAL ENERGY CONFERENCE (AWTEC) 2016

The Asian Wave and Tidal Energy Conference (AWTEC) has been established as the regional conference affiliated with the European Wave and Tidal Energy Conference (EWTEC) series to facilitate the transnational and regional sharing of knowledge and understanding from research of wave and tidal renewable energy systems, their interactions with the environment and the identification of barriers to establishing the marine renewable energy industry.

Energy Research Institute @ Nanyang Technological University (ERI@N) was chosen to be the host of the 3rd AWTEC 2016 conference series. ERI@N, together with Sustainable Energy Association of Singapore (SEAS), organized AWTEC 2016 was well attended by more than 350 attendees, including researchers, engineers from industries, techno-economists, policy makers and stakeholders. The conference was rich with 11 invited plenary speakers, 31 technical sessions with over 168 oral papers and 30 poster presentations that helped in rich exchange of knowledge through profound discussions that promoted international and multi-disciplinary collaboration. The conference spanned to a week of

events including preconference training workshops, three technical session days in the famous Marina Bay Sands venue (Singapore) and the last day of the week was dedicated to two technical tours (NTU Eco Campus and Floating Tidal Turbine Platform at LitaOcean Shipyard).
The conference drew support from 15 industry sponsors and had 11 exhibit booths during the conference where companies had the opportunities to display their technologies and expertise to the public. AWTEC 2016 was also supported by different embassies (Scotland, through Scottish Development International, Canada and The Netherlands) and intergovernmental organizations, like the ASEAN Centre for Energy (ACE).

Among the major achievements of the AWTEC 2016 are:

- MoU signing between OceanPixel and Aquatera;
- DP Energy entering South East Asian Marine RE Market;
- Envirotek, OceanPixel, Schottel Hydro, NTU, Aquatera (with support from Braemar Offshore, DHI, and ITP) progresses Tidal Demo Project for Singapore (~$500k);
- Green Forest Product and Technology Pte Ltd with PT BUMWI, in collaboration with Schottel Hydro, OceanPixel, Aquatera, and NTU announces Successful commissioning of a tidal turbine grid-connected pilot project in West Papua, Indonesia (~$500k);
- Over 30 companies from Europe (UK, Ireland, Germany), Canada, Japan, China, Australia participated in AWTEC 2016:
  - some notable names: Atlantis, DCNS, OpenHydro, WavePower, Albatern, Carnegie Wave, Schottel Hydro Scotrenewables, NovaInnovation, AW Energy, DP Energy, Tocardo;
  - Local: Braemar Offshore, Fugro, DHI, Lita Ocean,
- Continuous support form ASEAN Centre for Energy (ACE) towards Southeast Asian Collaboration for Ocean Renewable Energy (SEACORE);
- SEACORE-SEAMEC (Southeast Asian Marine Energy Centre) Collaboration.

Asian Wave and Tidal Energy Conference (AWTEC) 2016.

SPAIN

JOSÉ LUIS VILLATE *TECNALIA, in collaboration with APPA-Marina*

INTRODUCTORY NOTE

2016 has seen the first floating wave energy device connected to the grid in Spain. The so called MARMOK-A-5 device, developed by **OCEANTEC**, was deployed in October at **BiMEP** and grid connected, delivering the first kWh in December. The technology development has been supported by **EVE** (the Basque Energy Agency) under a Pre-commercial Procurement Contract and the testing activities at **BiMEP** are also part of the European project **OPERA,** led by **TECNALI**A. Another milestone in 2016 has been the installation of an offshore platform at PLOCAN, which together with the electrical infrastructure expected in early 2017 will allow **PLOCAN** to be fully operational during the first semester of 2017.

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.
One Spanish region has defined specific strategies and targets 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 60MW by 2030.

REGULATORY FRAMEWORK

In Spain no dedicated consenting process exists for ocean energy technologies 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. This Decree foresees a simplified procedure governed by Royal Decree 1955/2000 regulating energy transport, distribution, commercialisation, supply and the authorisation procedure for electrical power plants.
- Law 2/2013, of 29 May, for protection and sustainable use of coastal and amending the previous Coastal Law of 1988. It provides the legal framework for occupation of the territorial sea, as well as governing issues affecting the fishing sector and safety conditions for maritime navigation.
- Law 21/2013, of 9 December 9, 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 currently. However as a result of the pre-commercial public procurement tender launched by EVE in November 2014 and awarded to OCEANTEC in 2015, a floating oscillating water column concept device called MARMOK-A-5 was successfully installed in October 2016 at BiMEP.

PUBLIC FUNDING PROGRAMMES

There are several R&D public funding programmes in Spain not specific for ocean energy but applicable in competition with other sectors. In addition, there are a couple of programmes more specific for ocean energy:

- The European network OCEANERA-NET, participated by the Spanish Government through CDTI and agencies from Asturias, Cantabria, Basque Country and the Canary Islands, launched a second call in 2016 with the aim of funding projects to support research and innovation in the ocean energy sector. CDTI and EVE (Basque Country) have been also working on a continuation of this network to secure a new call in 2017 under a co-funding mechanism with the European Commission.

- In the Basque Country, a new call to support open sea testing was launched by EVE in 2016. The purpose of this programme is the demonstration and validation of emerging marine renewable energy technologies.

RESEARCH & DEVELOPMENT

In February 2016, a consortium led by TECNALIA in partnership with University of Edinburgh, University of Exeter, University College Cork, Instituto Superior Técnico, OCEANTEC, EVE, BiMEP, Global Maritime, Iberdrola, Kymaner and DNV-GL kicked off the **OPERA** project funded by the European Commission under the Horizon 2020 programme. The project entitled "Open Sea Operating Experience to Reduce Wave Energy Cost" will collect and share two years of open sea operating data of the floating OWC wave energy converter developed by Oceantec and already installed at BiMEP. In addition, OPERA will be the first open sea experience for four cost-reducing innovations that will be advanced from TRL3-4 to TRL5. Together, these four innovations have a long-term cost reduction potential of over 50%. These are: an efficient turbine, latching and predictive control, a shared mooring system for wave energy similar to those that have reduced mooring costs in aquaculture and an elastomeric mooring tether that reduces peak loads at the hull-mooring connection and thus addresses one of the most pressing challenges for structural survivability of wave energy devices. Documenting and sharing this open sea experience will also induce a step-change in the knowledge of risk and uncertainties, costs and societal and environmental impacts of wave energy. The consortium brings together world leaders in wave energy research, the IPR owners and most advanced teams to exploit each of these innovations.

Within the OCEANERA-NET programme, 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 aims to answer the challenge of identifying common components in ocean energy technologies by developing a set of industry-enabling 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. Also under OCEANERA-NET, 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.

The end of 2016 brought the approval and contract signature of the **MARINET2** project, funded by the European Commission under the Research Infrastructure section of H2020. MARINE2 will continue the success of MARINET project, ensuring the integration and enhancement of all leading European research infrastructure and facilities specialising in research, development and testing of offshore renewable energy systems including electrical sub systems and grid integration through a range of TRLs (1-7). The project is expected to start in early 2017 with the participation of 7 Spanish partners: BiMEP, CENER, CTC, EVE, IH Cantabria, PLOCAN and TECNALIA.

TECNALIA is leading the project **ICERMAR**, funded by the Basque Government, in collaboration with the University of the Basque Country and the Basque Centre for Applied Mathematics to coordinate research efforts in the field of marine renewable energy (ocean energy and offshore wind). Six research lines have been under development during 2016: development of new modelling tools; new PTO concepts for OWC wave energy devices; corrosion, fatigue and anti-fouling materials, mooring systems and electrical connections, performance assessment and environmental issues.

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.

Two research projects are under development involving PLOCAN: the project **ORPHEO** has been awarded by the Spanish Ministry to analyse the profitability of hybrid floating platforms to harness wind and wave energy together. The project consortium is composed by INGETEAM, ENEROCEAN, University of Cadiz, University of Malaga and PLOCAN. The project **DESAL+** has been awarded within an INTERREG-MAC call, where PLOCAN will analyse the potential use of wave energy in desalination process.

During the last years, **SENER** has carried out two lines of work: one consisting of the development and design of its own technology (based on the OWC principle) and main equipment (air turbine and check valves), and another line where SENER has developed its own software for simulating, design and calculation of wave energy converters and farms, which allows the optimization of devices and arrays, as well as the calculation of project costs, including LCOE, for each location.

Within an individual R&D programme, **Rotary Wave**, a Spanish technological start up, received €600.000 funding from CDTI to research and develop the Butterfly WEC device, which uses wave energy to obtain electricity and desalinated water. As a first step, Rotary Wave tested and validated a 1:13 scaled device in A Coruña University's Wave Tank in order to obtain TRL4. In these tests, the Butterfly device showed its capacity to produce power (120 kW equivalents with 3 m real waves) in addition to good stability and survivability conditions.

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

The Biscay Marine Energy Platform (**BiMEP**), promoted by EVE and IDAE, is in operation since its inauguration in July 2015. BiMEP is an open sea test centre of 5.2 km2, restricted to sea traffic, with depths going from 50 to 90 m. It is located in an area with high energy potential (21 kW/m) and its proximity to the nearest port (1 nmi) guarantees fast access. The area has a strong and nearby coastal utility grid (132 kV-20 MW capacity). BiMEP is equipped with four berths of 13,2 kV/5 MW each connected to the grid, environmental monitoring services and 24/7 surveillance and emergency response. BiMEP hosts the first floating wave energy device connected to the grid in Spain (more information about this project in section 5 about Technology Demonstration). There are other projects that are carrying out trials at BiMEP but without grid connection. This is the case of ZUNIBAL S.L. that is testing the ANTEIA low cost metocean buoys.

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. One of the air chambers is prepared to test OWC components (air turbines, electrical generators, power converters and control systems) and has been used by Oceantec to test its air turbines before installing them in the MARMOK-A-5 device at BiMEP.

PLOCAN offers a test site for marine energy converters among other uses. It includes an offshore platform, which has recently been fixed to the seabed at the north-east of Gran Canaria Island: 1.5 km from shore at 30 m depth. Following successful completion of the mooring procedure, the operation was completed on 1 December, leaving the platform resting on a previously prepared base on the seabed. The platform is a multipurpose infrastructure providing workshops, laboratories, classrooms, training rooms and open working areas around a test tank to facilitate sea trials and launching vehicle to the sea. It is expected to be fully operational during the first semester of 2017. Two submarine medium voltage cables are expected to be installed in the first quarter of 2017, which will allow delivering the electricity generated by devices under testing offshore. The initial capacity is set up at 15 MW with a future extension planned up to 50 MW by 2020. Three wave energy devices have already been tested at PLOCAN without grid connection (Wedge, Wello and Pipo System). PLOCAN is also hosting offshore wind demonstration projects such as the ELICAN project led by the Spanish company ESTEYCO: a 5 MW offshore wind turbine prototype will be installed in 2017 over a telescopic mast with a gravity based mooring.

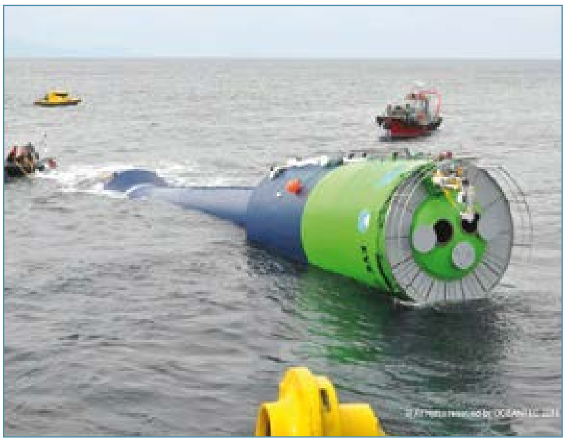
Installation of PLOCAN offshore platform

OPERATIONAL PROJECTS

The **Mutriku wave power plant** has completed its first five years of continuous operation reaching a record of cumulative energy produced from waves with more than 1.3 GWh injected into the power grid.

Mutriku wave power plant

The Basque company **Oceantec Energías Marinas**, promoted by TECNALIA and Iberdrola, has recently deployed its first Wave Energy Converter (WEC) at BiMEP. The transport to site operation of the WEC, so-called MARMOK-A-5, and its installation at BiMEP was completed on 12 October. Oceantec has been working on the development of its own wave energy conversion technology over the last 4 years. It is a point absorber based on the Oscillating Water Column (OWC) principle. The prototype installed at BiMEP resembles a large floating buoy of 5 metres in diameter, 42 metres in length and 80 tonnes weight. The generating system comprises two air turbines located in the upper part of the device with a rated capacity of 30 kW. The turbines were previously tested at Mutriku wave power plant. The device was connected to the grid in early December delivering the first kWh on 13 December. The technology development has been supported by the Basque Energy Agency – Ente Vasco de la Energía (EVE) under a Pre-commercial Procurement Contract. The testing activities of the WEC are also part of the European project OPERA, already mentioned in the previous section.

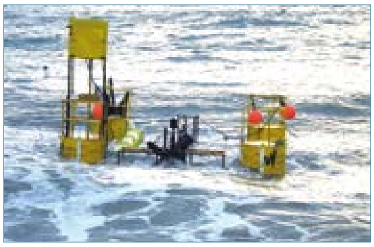


FMARMOK-A-5 device, developed by Oceantec, during its installation at BiMEP

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 to be expectedly concluded by 2017. The Project is based on the industrial-scale W1, which 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 under open-ocean & harbour tests at PLOCAN site in the Canary Islands (achieving non-stop tests & wave power generation results for the period 2014-2016).

UNDIGEN+ wave energy device at PLOCAN

After wave tank testing, **Rotary Wave** has developed a higher scale device (1:4) to demonstrate the Butterfly technology in a relevant environment (Mediterranean Sea). The device was designed to provide 10 kW and from the experiences obtained, study data of power was around 7 kW. The Butterfly device was tested in Pobla de Farnals (Valencia,Spain), where local average waves are around 0.5 m, therefore the power obtained was a successful result. The project was finished in September (2016) with outstanding and promising results.



Butterfly device experiences in Mediterranean Sea (Valencia, Spain)

PLANNED DEPLOYMENTS

The Spanish company **EnerOCEAN l**eading the WIP10+ project plans to install a prototype of a floating platform, including offshore wind turbines and wave energy converters, at PLOCAN to be tested during 2017.
After the experience with the 1:4 scaled device, **Rotary Wave** is up and expecting to install a device connected to the grid in 2017.

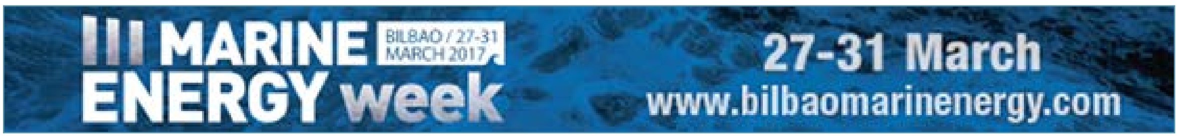
Galicia-based Magallanes Renovables expects to start testing a 2 MW prototype of a floating platform with submerged tidal turbines in February 2017. This will start in a location near Vigo, before being transferred to EMEC in Scotland. There they will study the equipment under real operating conditions over a period of one year.

OTHER RELEVANT NATIONAL ACTIVITIES

ICEX España Exportación e Inversiones, in collaboration with the Commercial Office of Spain in London, organized for the first time a Spanish space in **ICOE** (the International Conference on Ocean Energy), which celebrated its sixth edition in February 2016 at the Edinburgh International Conference Centre. The Spanish institutional participation, led by APPA Marina, occupied an area of 18 m^2 with the following participants: APPA Marina, BiMEP, IH Cantabria, PLOCAN, Rotary Wave and TECNALIA.

APPA-Marina, jointly with the Naval Engineering School of Madrid and CME (Spanish Maritime Cluster), organized the **second edition of the National Annual Conference on Marine Renewable Energy** in Madrid in November 2016. 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 third edition of the Marine Energy Week has been announced to be held in Bilbao in the last week of March 2017. This event, organized by EVE, TECNALIA and the Bilbao Exhibition Centre, will bring 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 in a wider event about maritime aspects including networking and B2B spaces.



SWEDEN

MARIA OLSSON *Swedish Energy Agency*

INTRODUCTORY NOTE

During 2016, the Swedish Energy Agency held the 30th OES Executive Committee Meeting. In conjunction with this an ocean energy conference was held with both international and Swedish participants.

During the year, a second call for funding ocean energy projects has been carried out for both the European cooperation OCEANERA-Net and the national programme Marine Energy Conversion. The Swedish wave power company CorPower together with partners has also received funding from the European Commission for improving reliability and performance of novel direct drive PTOs.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The Swedish energy policy is based on the same foundations as energy cooperation in the European Union (EU) and seeks to reconcile environmental sustainability, competitiveness and security of supply. In 2016, the Government, together with several other political parties, agreed on a long-term energy policy for Sweden. The agreement includes a goal that by 2040 Sweden will have 100 percent renewable electricity production. Further on, by 2045, there will be no net emissions of greenhouse gases in the atmosphere.

In 2015, the Ministry of Enterprises, Energy and Communications finished their work on a national maritime strategy which has identified areas where actions are needed in order to promote a sustainable development in the Swedish maritime sector. Ocean energy is one of many areas which are included.

MARKET INCENTIVES

Fundamental to the long-term Swedish energy policy are general economic policy instruments such as carbon tax, international emissions trading and tradable certificates for renewable electricity. From the perspective of ocean energy technology development, the renewable electricity certificate system (a tradable green certificate system) is the most relevant policy instrument.

The electricity certificate system is a market-based support system for cost-effective expansion of electricity production from renewable sources. By design, the system does not specifically target a particular renewable electricity conversion technology, i.e. is technology neutral. Electricity certificates are issued to those who produce electricity from one or more renewable energy sources, or from peat, and who have had their production plants approved by the Swedish Energy Agency. To date, certificates have been issued to producers of electricity from biofuels and peat, wind power, hydro power and solar electricity.

In 2011, Sweden and Norway entered into an agreement to form a joint electricity certificate market, which has been in operation since the beginning of 2012. Together with Norway, annual production from renewable sources in 2020 shall have increased by 28,4 TWh relative to production in 2012. In the agreement made in 2016 of the long-term energy policy for Sweden it was decided that the electricity certificate system will be prolonged to 2030 and with additional 18 TWh of renewable electricity.

PUBLIC FUNDING PROGRAMMES

The main public funding mechanism for research, business and technology development and technology demonstration are Swedish governmental agencies tasked to support academic and private sector R&D in the various stages of innovation. There are a number of governmental agencies from which researchers and developers can apply for funding.

- The Swedish Energy Agency, www.energimyndigheten.se, is the Swedish agency responsible for facilitating a sustainable energy system in Sweden. As such, the agency funds research, business and technology development and technology demonstration which is relevant for the sustainability of the energy system and the sustainability of 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 are able to grant funding to varying extents.

In the beginning of 2015, the Swedish Energy Agency started a national ocean energy programme that will run for four years with a total budget of around €5,7 million (53 MSEK). The aim is to strengthen the research and development being done in the area and increase the cooperation between and within academia and industry. A total of 16 projects have been approved for funding within the programme. The programme will now be evaluated before any new calls. In parallel, there is ongoing work with a strategy for research and support to marine energy that will be used by the Swedish Energy Agency.

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

RESEARCH & DEVELOPMENT

Swedish companies, universities and institutes have been involved with several research and development projects during 2016. Below are just a few examples of these R&D projects:

WAVEBOOST

Participants: CorPower Ocean AB, EDP Innovation, EMEC, University of Edinburgh, WavEC, SP, GS Hydro and PMC cylinders

The project, that has received funding from the European Commission, focus on reliability and performance of novel direct drive PTOs. The efforts are expected to increase energy production, reduce CAPEX and improve grid integration of wave energy farms, resulting in a reduction in the cost of energy of up to 30 percent.

PREDICTION AND MITIGATION OF SNAP LOADS IN MOORING LINES

Participants: Chalmers University of Technology, CorPower Ocean AB, Seaflex Energy Systems AB

The project deals with the problem of snap loads in mooring cables of floating wave energy converters. New numerical methods for snap load propagation will be developed and used to assess snap load probability and magnitude in existing mooring design types. In particular, the snap load mitigating effect of the Seaflex® mooring material will be studied. The project will further design and develop a new solution for snap elimination in tension leg mooring systems. The solution will be specifically tailored for mooring the CorPower Ocean buoy, but it has potential use also for tension leg platforms for floating wind energy and other WECs. Field measurements and laboratory testing of the mooring response will be used to validate the numerical method and act as input to an optimisation of the design.

A NEW GENERATION OF PERMANENT MAGNET GENERATORS FOR MARINE ENERGY CONVERSION

Participants: Uppsala University, Seabased AB, Fortum Power and Heat AB

The project aims at using scientific methods to improve the design of slow moving, permanent magnet generators for marine energy conversion. The goal is to develop generators that have better performance, reduced cost, increased reliability, improved reproducibility and are more environmental friendly.

KITE FLIGHT: OPTIMIZATION OF OCEAN BASED POWER PLANTS

Participants: University of Gothenburg, Chalmers University of Technology, Minesto AB

All large scale flows in the ocean and atmosphere are fully turbulent, and tidal currents are no exception. The small scale variability connected to turbulence is an important factor to consider when designing equipment to work in a turbulent tidal current. In the present project, state-of-the-art numerical models are considered (belonging to the class of Large Eddy Simulation, or LES models) to quantify the turbulence levels in a realistic tidal flow situation. The target area is Holyhead Deep outside Wales. Turbulence levels in an ordinary tidal cycle as well as the case with an embedded tidal power plant will be considered, here the levels of added turbulence is targeted as well as its decay downstream. Together with the company MINESTO they will also evaluate the impact of the natural turbulence on the Deep Green Technology developed by the company.

MAPPING OF OPPORTUNITIES FOR OFFSHORE WAVE ENERGY CONVERSION IN THE SWEDISH EXCLUSIVE ECONOMIC ZONE

Participants: Uppsala University, Geological Survey of Sweden, IVL Swedish Environmental Research Institute

In a new research project, Uppsala University and partners will study a variety of meteorological and geological variables of relevance to the establishment and operation of offshore wave energy conversion systems of point absorber type for high resolution mapping in the Swedish exclusive economic zone. Parameters to be studied include wave climate, seasonal ice conditions, water level fluctuations, sea depths and conditions on the seabed, surface current influence on drifting ice, regional environmental factors, protected and regulated areas, waterways, among other things. The technical wave energy potential will be predicted in various scenarios established through large park simulations of generic wave energy units of point absorber type through validated time domain models developed at Uppsala University. The most favourable zones for establishment of pilot sites with respect to the studied variables and simulated results will be identified and classified.

DEVELOPMENT OF A DURABLE WINCH SYSTEM FOR WAVE POWER

Participant: Royal Institute of Technology

The project aims to develop a rotating PTO system with a winch based solution. The focus is to develop the winch that has a much longer lifetime than ordinary chains.

COST EFFICIENCY OF MARINE POWER PLANTS

Participants: SSPA, Minesto AB, Moorlink Solutions AB

The project includes the development of the Minesto system with respect to: a) Design Optimization of control surfaces – rudders, b) Full scale effects going from ¼-scale to full scale, and c) Anchorage system.

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. At the site, not only the wave energy technology is studied, but also how a wave energy park may influence the local marine environment. A Datawell Waverider wave measuring buoy was installed in 2004 and measures the waves at the site continuously. The first full scale wave energy device was installed in 2006. Since then, a large number of wave energy generators, buoys, marine substations and various wave energy technologies have been deployed and studied in a long series of experiments at the site. The test site has been grid connected since November 2015.

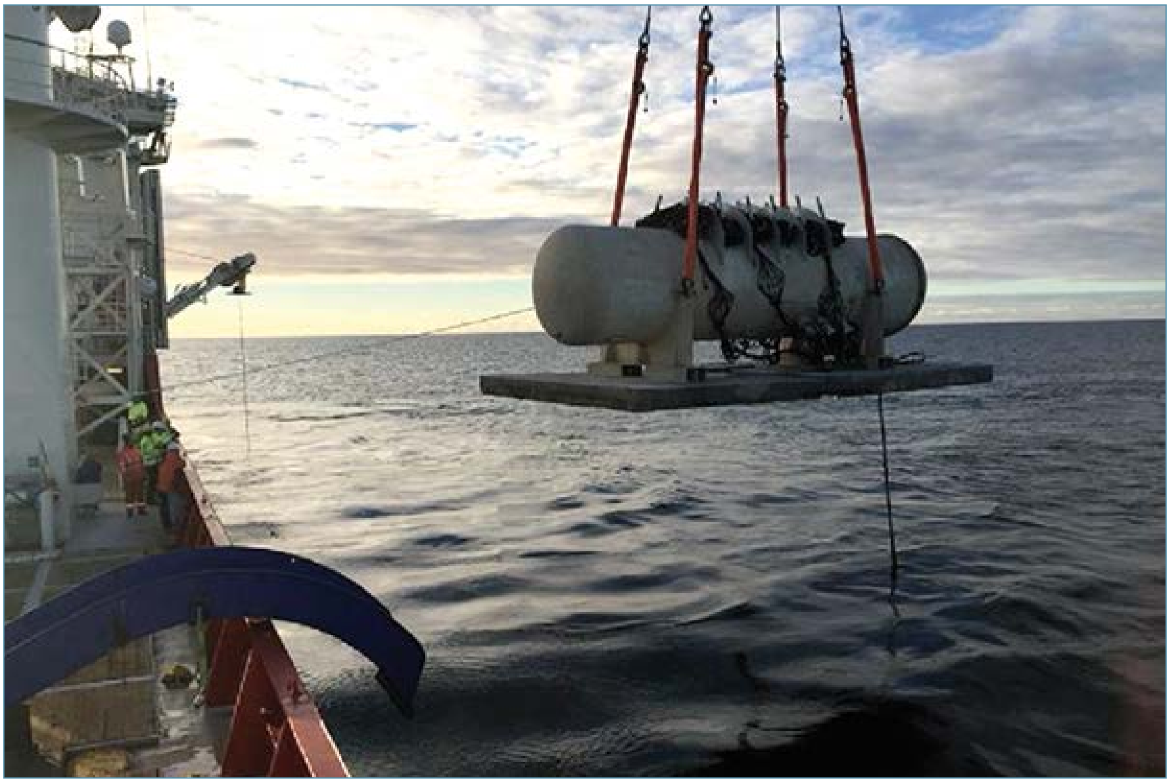
OPERATIONAL PROJECTS

The only projects executed in Sweden and operational 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 the Lysekil site preparations have been made during 2016 for next year´s grid connection of three wave energy converters. If successful, it will be the first time the group has an array of wave energy converters connected to the grid. Environmental studies have also been completed including measuring and tagging of crustaceans at the wave power test area and control areas and status of colonization of fish and crabs. Further on, an active acoustic system for subsea environmental monitoring of marine energy technologies and farms has been tested.

At Söderfors site, the turbine blades have been changed during 2016 and the vertical marine current converter has been grid connected.

The **Sotenäs Project** was initiated in November 2011 and 36 wave energy converters (corresponding to 3 MW) has been deployed along with the subsea generator switchgear. The wave power plant was initially grid connected in January 2016. The Sotenäs Project is funded by the Swedish Energy Agency, the power company Fortum and by Seabased Industry AB. The technology is based on a point absorber connected to a linear generator on the sea bed.



Deployment of the low voltage marine substation in the Sotenäs project

Waves4Power is another Swedish company demonstrating one full scale wave power device at sea; however the demonstration takes place in Runde, in Norway. Grid connection is planned to be completed in 2017.

Waves4Powers buoy demonstrated in Runde, Norway

PLANNED DEPLOYMENTS

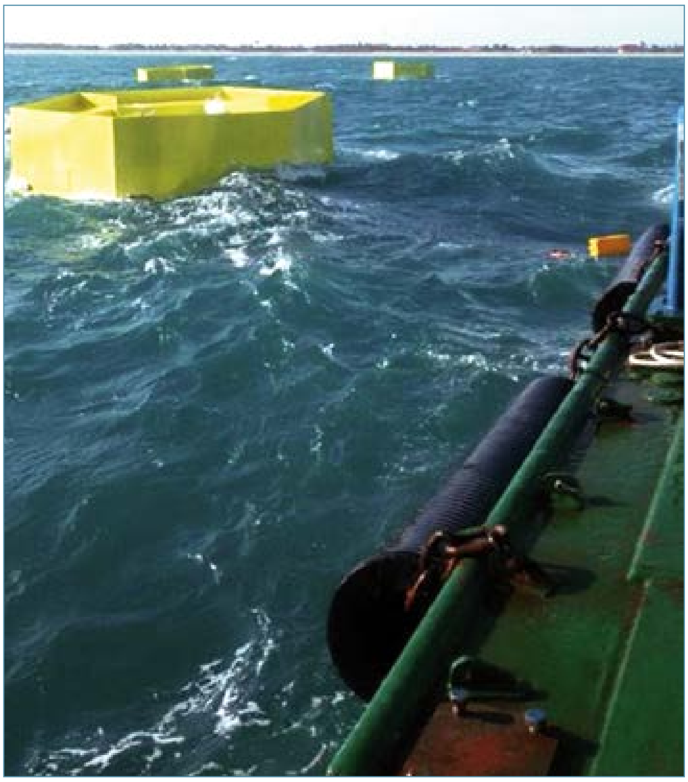
The deployments that are planned in the near future will take place outside Sweden:

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 has been successfully continued during 2016, as Minesto demonstrated test results which surpassed noted maximum levels of electricity generation. During the year, great progress has been made in design and control system.
In 2017, Minesto plans to build and commission the first demonstrator of the Deep Green technology at commercial scale. The device will be installed at Minesto's site in Holyhead Deep, some 8 km outside the coast of northern Wales. In Holyhead Deep, for which Minesto holds an Agreement for Lease from the Crown Estate, the company will gradually expand installed capacity to a 10MW commercial array (20 Deep Green units). Minesto has received funding from KIC Innoenergy and European Regional Development Fund through the Welsh Government.

CorPower Ocean develops compact high efficiency Wave Energy Converters, inspired by the pumping principles of the human heart. The company is headquartered in Stockholm, with activities in Sweden, UK, Norway and Portugal.
CorPower Ocean is currently performing its Stage 3 pilot programme. This entails taking a 1:2 scale Wave Energy Converter through the next step of structured verification by dry testing it in a Hardware-in-the-loop rig in Stockholm from late 2016 until mid-2017, followed by wet testing at EMECs Scapa Flow nursery site in Orkney, Scotland, through 2017. The project is funded by the Swedish Energy Agency, KIC Innoenergy, and Wave Energy Scotland. CorPower has also received funding through ForeSea, an Interreg project by the European Commission for an extended period of ocean testing. Stage 3 development and verification activities are supported by best practice from the European Marine Energy Centre (EMEC) in Orkney, alongside the experience from offshore power generation company Iberdrola Engineering and EDP, the University of Edinburgh, NTNU, in Trondheim, and WavEC Offshore Renewables in Lisbon.

Stage 3 of CorPower's device (in composite hull)

Seabased has signed a contract for a wave energy park in Ghana. The Ada Project in Ghana was initiated in November 2014 and the first wave energy converters and switchgear have been delivered to Ghana and are under installation. The wave power plant is the first step in a facility that when completed is planned to reach 200 MW.



Seabased's wave energy devices under installation in Ghana

OTHER RELEVANT NATIONAL ACTIVITIES

In May 2016, the Swedish Energy Agency arranged the 30th OES ExCo Meeting. In conjunction with this, an ocean energy conference has also been held with both Swedish and international participants from OES, OCEANERA-Net and Ocean Energy Forum. The conference covered, amongst others, presentations and discussions on challenges and solutions for ocean energy and gave input to the Strategy for Marine Energy for the Swedish Energy Agency.

StandUp for Energy is a research alliance between Uppsala University, KTH, Swedish University of Agricultural Sciences and Luleå University of Technology, focusing on areas such as renewable energy production (marine energy included), electricity grid, electric and hybrid vehicles and energy system. Conferences are held twice a year and are attended by companies and policy makers.

Swedish Maritime Day, which is held every year, gathers stakeholders from academy, industry and the public sector. The conference is not only focused on offshore energy but also in areas like shipping, biotechnology, marine environment etc.

In the beginning of 2017, the new dry testing facility of CorPower will be inaugurated in Stockholm, combined with a scientific programme involving presentations from leading European research groups.

UNITED KINGDOM

HENRY JEFFREY *The University of Edinburgh*

INTRODUCTORY NOTE

2016 has been another active year for the ocean energy sector in the United Kingdom (UK). Several significant and internationally relevant developments have been made across the wave, tidal stream and tidal range segments, while the political and regulatory setting for the sector has continued to evolve. The promise of ocean energy remains strong and there is potential for wave and tidal energy to contribute significantly to the UK's electricity supply in the run up to 2050, subject to reducing costs and achieving competitiveness with alternative technologies.

Wave

Following several years which have been characterised by retrenchment, the UK wave energy sector is refocussing and engaging in targeted research and development to optimise technologies and move towards convergence of design and commercialisation. This approach is epitomised by Wave Energy Scotland (WES), a Scottish government funded technology development programme which has so far awarded £15m to 51 technology development projects in the areas of power take-offs (PTOs), novel devices and structural materials & manufacturing processes.

Tidal Stream

The UK's tidal stream sector made significant progress towards commercialisation in 2016, with a number of turbine deployments including two at array scale. The MeyGen project in Scotland's Pentland Firth is close to completing construction of Phase 1A of the project, involving 4 turbines and a capacity of 6MW. Long-term plans for MeyGen allow for up to 398 MW within the next decade. Meanwhile, Nova Innovation began exporting power to the grid following the successful installation and operation of 2 turbines off the coast of Scotland's Shetland Isles. Following the award of funding under the European Union's Horizon 2020 programme, Nova intend to further develop the Shetland array in 2017.

Tidal Range

Policy in relation to tidal lagoons developed significantly in 2016 with a government commissioned review of the strategic role of tidal lagoons in the UK, led by former energy minister Charles Hendry. A final report was published in January 2017 and supports the development of tidal lagoons, highlighting the benefits of a "pathfinder" project ahead of a wider programme. A Government response to the Hendry Review is anticipated in due course. The proposed Swansea Bay tidal lagoon project continues to move through the consenting process with a view to begin construction in 2018.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

A restructuring of government departments in 2016 led to the Department for Energy and Climate Change (DECC) being absorbed into the new department for Business, Energy and Industrial Strategy (BEIS). BEIS retains overall responsibility for energy policy in the UK although many powers related to energy have been devolved to the governments of Scotland, Wales and Northern Ireland.

The UK government continues to offer revenue support to a variety of renewable energy technologies through the Contract for Difference (CfD) programme. Based on a "strike price", CfDs offer long-term price stabilisation and are awarded via competitive auctions. The next round of auctions, worth £290m per annum, will open in April 2017. Strike prices of £310/MWh for wave and £300/MWh for tidal stream are being mooted for projects due to deploy in 2021/22. However, bids for wave and tidal stream CfD allocations are made in competition with other "less established technologies" in a pot of that includes offshore wind and biomass.

TECHNOLOGY	2021/22	2022/23
Offshore wind	105	100
Advanced conversion technologies (with or without CHP)	125	115
Advanced conversion technologies (with or without CHP)	140	135
Dedicated biomass with CHP	115	115
Wave	310	300
Tidal stream	300	295
Geothermal	TBC	TBC

UK Contract for Difference for less established technologies: Draft strike prices (£/MWh)

Scotland

Scotland has tremendous wave and tidal energy resources (a third of the UK's tidal stream resources and two thirds of the UK's wave resources) and the potential exists to generate more electricity than needed from the waters around the Scottish coast.

The ocean energy sector in Scotland has progressed more in 2016 than in any previous year, with several world firsts achieved:

- Edinburgh firm Nova Innovation has deployed the first two turbines of the Shetland Tidal Array and is exporting power to the Shetland grid;
- Atlantis Resources Limited has almost completed construction of the first phase of the MeyGen project – the world's largest planned tidal stream array; and
- Orkney-based Scotrenewables has begun testing the world's most powerful floating tidal turbine at the flagship European Marine Energy Centre.

The Scottish Government remains strongly committed to the development of a successful ocean power industry in Scotland and to maintaining the current strong lead in this area. The Scottish Government established Wave Energy Scotland (WES) in 2014 to support 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 committed £12m in funding in 2016 and recently announced 10 awards totalling £3 million for structural materials and manufacturing processes projects. WES expects to run a further call for control systems in spring 2017.

The Renewable Energy Investment Fund (REIF) – designed to help ocean energy projects take the leap towards commercialisation– has so far invested over £40 million in a range of innovative wave and tidal schemes.

There are, however, challenges ahead. The impact on the industry of exiting the EU is not yet clear, but it is known that the marine energy sector in Scotland has benefited significantly from EU funding, which is now in some doubt. Added to that, the UK Government's decision not to provide ring-fenced support for wave and tidal stream technologies in its subsidy scheme will have an impact on investor appetite and may reduce the attractiveness of the UK for marine energy developers.

Scotland has worked collaboratively over the last year with its UK and European colleagues to identify and address the barriers facing the development of the ocean energy sector. This work was accomplished through active participation in a range of groups and workstreams, including the energy workstream of the British-Irish Council; the European Commission's Ocean Energy Forum; and through leadership of a Horizon 2020 Ocean ERA-NET Cofund. Scotland will continue to work closely with technology and project developers, the supply chain, academia and public sector partners to unlock the potential of the UK's marine energy industry.

Wales

The Welsh government remains in strong support of the ocean energy sector and spent 2016 putting in place several initiatives to support development of the sector. In addition to the positive message given by the Hendry review on tidal lagoons, Welsh government policies look set to promote the standing of the nation on the international ocean energy stage.

Over £1m has now been invested via the Marine Renewable Energy Strategic Framework which is carrying out large-scale investigations in to the Welsh marine energy resource and the infrastructure requirements of ocean energy developments. The Welsh government also regularly engages with the Crown Estate to improve access to maritime areas suitable for development.

2016 saw the renaming of Marine Energy Pembrokeshire to Marine Energy Wales. This Welsh government supported initiative is a partnership between developers, academia, the supply chain and the public sector with the aim of developing a Welsh marine energy centre of excellence. The organisation has developed closer links with Wave Hub through a management agreement for their proposed South Pembrokeshire Demonstration Zone.

Northern Ireland (NI)

DP Energy's Fairhead Tidal project continued to move through the survey and consenting phases of development in 2016 with the support of the Northern Irish Government. 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. The NI Department of Agriculture, Environment and Rural Affairs (DAERA) is working to develop a Marine Plan for NI, with the aim of guiding the regulation, management use and protection of maritime regions.

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. Perhaps most notably, the Crown Estate and UK and Scottish Governments are working to enable the transfer of The Crown Estate's management duties in Scotland to the Scottish Government, as recommended by the Smith Commission and reflected in the Scotland Act 2016. It is expected that discussions, including public consultation, will continue through the first half of 2017.

The Crown Estate in Scotland includes a diverse portfolio of property, rights and interests that influence many aspects of rural and coastal life in Scotland. The new functions being devolved include rights to the seabed and management rights over around half the foreshore of Scotland. Taking on the Crown Estate's role in the management of seabed rights out to 200 nautical miles 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 PROGRAMMES

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 will support wave energy technology development until the technical and commercial risks are low enough for private investment to re-enter the sector.
http://www.hie.co.uk/growth-sectors/energy/wave-energy-scotland/

RESEARCH & DEVELOPMENT

KEY R&D INSTITUTIONS

The Offshore Renewable Energy Catapult (ORE Catapult)

The Offshore Renewable Energy (ORE) Catapult came into operation in 2013. 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. It is one of seven Catapult centres set up to bridge the gap between research and commercialisation in the UK. By analysing and prioritising industry issues and by active involvement in current research developments, the ORE Catapult will initiate programmes to accelerate the development of innovative engineering solutions.

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. Facilities include powertrain testing, still water docks, simulated seabed, component testing, high voltage laboratory and wind turbine blade testing. ORE Catapult participate in various wave and tidal stream related projects, such as looking at improvements to the reliability of tidal turbine powertrains.

Supergen

The Supergen programme was set up in 2001 to deliver sustained and coordinated research on Sustainable PowER GENeration and supply. The Supergen UK Centre for Marine Energy Research (UKCMER) entered its sixth year of operation in 2016 and continued to coordinate UK research into wave and tidal energy technologies.

During 2016, a review of the Supergen programme by the Engineering and Physical Sciences Research Council (EPSRC) concluded that, from mid-2017, the Wind and Marine hubs should be amalgamated in to a new Offshore Renewable Energy hub, allowing for better identification of synergies between the sectors.

KEY R&D PROJECTS

DTOcean

The 3 year long DTOcean project came to a conclusion in 2016. DTOcean (Optimal Design Tools for Ocean Energy Arrays) was a collaborative research and development project funded by the European Commission. It gathered 18 partner organisations from 11 countries and was co-ordinated by the University of Edinburgh. DTOcean aims to accelerate the industrial development of marine energy by creating software tools for the optimised design of first generation wave and tidal energy converter arrays.

The complete DTOcean software package includes the following computational modules:

- Hydrodynamic Array Layout
- Electrical System Architecture
- Moorings & Foundations
- Array Installation
- Operations & Maintenance

Given a set of user inputs regarding the chosen wave or tidal energy converter and array location, DTOcean identifies optimal layouts, components and procedures in each of the above modules. Optimality is established at array lifecycle level, taking into account dependencies between each module, and is defined in terms of three key metrics: Levelised Cost of Energy (LCoE); Reliability; and Environmental Impact.

TECHNOLOGY DEMONSTRATION

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 two grid-connected test sites – one for tide 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.

2016 saw EMEC host more new demonstration projects, with 27 devices from 17 companies now having been tested on site. EMEC's alumni include the first tidal turbines at the MeyGen site from Atlantis and Andritz Hydro Hammerfest, as well as longest standing client OpenHydro installing a turbine in the Bay of Fundy (a scaled-up version of the 6m turbines they have been testing at EMEC since 2007). Scotrenewables' 550-tonne 2MW tidal turbine arrived at EMEC in 2016, as well as Sustainable Marine Energy (SME) who successfully installed four subsea drilled rock anchors at its Fall of Warness for their first PLAT-O system, which hosts two SCHOTTEL Instream Turbines (SIT).

One of the biggest EMEC projects starting in 2016 was the launch of FORESEA – a new €11m European programme to support open sea testing for ocean energy. Led by EMEC, the FORESEA (Funding Ocean Renewable Energy through Strategic European Action) project provides funding support to ocean energy technology developers to access Europe's world-leading ocean energy test facilities. The first call for applications was closed in September, with ten successful ocean energy developers announced.

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 late 2016, 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. As work on this development ramps up, Wave Hub continues to focus on environmental survey and consenting work.

OPERATIONAL DEPLOYMENTS

MeyGen

The MeyGen array, operated by Atlantis Resources in Scotland's Pentland Firth, made significant construction progress in 2016. 2017 is due to be spent expanding the array to a capacity of 6 MW, thus completing phase 1A of the project. Full capacity across all phases is to be up to 398 MW.

Nova Innovation Shetland

Nova Innovation are currently exporting power from two turbines installed off the coast of Shetland in Scotland, with a third turbine due to go live in early 2017.

PLANNED DEPLOYMENTS

EMEC

Several wave and tidal developers (including CorPower, Laminaria, Tocardo Tidal Power and Nautricity) are due to run test and demonstration projects at EMEC in the course of 2017.

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 and up to 10 MW, while the full scale array is likely to be in the region of 100 MW capacity.

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. Consent was awarded in 2015 and the company plans for construction to begin in 2018.

Carnegie Wave Hub

Carnegie Clean Energy have entered an agreement to install a 15 MW array at the Wave Hub site in Cornwall, England, using their CETO 6 wave energy converter.

Tidal Power Scotland Ltd (TPSL)

Atlantis Resources is the majority owner of the TPSL holding company. TPSL holds the rights to develop several tidal energy projects in Scotland including Sound of Islay, Ness of Duncansby, Brough Ness and Mull of Galloway.

USA

STEVEN BUSHONG, ALISON LABONTE AND ANN DALLMAN *US Department of Energy*

INTRODUCTORY NOTE

With more than 50 percent of the U.S. population living within 50 miles of coastlines, marine and hydrokinetic (MHK) energy technologies provide America an opportunity to develop an untapped domestic energy resource. The U.S. Department of Energy's investments in MHK energy technology seek to advance an energy technology complementary to the nation's all-of-the-above energy strategy, while also encouraging domestic manufacturing, job creation, and seaport revitalization. U.S. MHK resource assessments identify a technical resource potential of up to 1,250 to 1,850 terawatt-hours (TWh) of generation per year. For context, approximately 90,000 homes can be powered by one TWh of electricity generation each year. A domestic MHK energy industry could provide reliable power to coastal regions, especially in areas with high electricity costs. In 2016, the American MHK sector made significant investments and efforts toward realizing commercial MHK energy technology, including the announcement of plans for a full-scale, grid-connected national wave energy test facility, the demonstration of a five-fold increase in wave energy capture potential with the culmination of the Wave Energy Prize, and numerous advances in technology maturity and reducing deployment barriers.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

In 2016, the U.S. Department of Energy (DOE) Water Power Technologies Office's MHK Program made significant efforts to gather stakeholder feedback and draft a National Strategy for Marine and Hydrokinetics. The draft strategy offers a vision, mission statement and strategic goals, which outline the MHK Program's role in helping to realize the vision. Each component is shared below.

Draft MHK Program Vision: A U.S. Marine and Hydrokinetic industry that expands and diversifies the nation's renewable energy portfolio by responsibly delivering energy from ocean and river resources

Draft MHK Program Mission: Support the development of safe, reliable, and cost-competitive MHK technologies and reduce deployment barriers

Draft Strategic Goals:
- Reduce the levelized cost of energy (LCOE) by 80% compared to the 2015 baseline LCOE values for wave (0.84 $/kW-h) and current (0.58 $/kW) technologies by 2030
- Enable the industry to rapidly increase MHK technology deployments by supporting research and stakeholder outreach activities to reduce deployment barriers and to accelerate project permitting processes

Key challenges in realizing these goals were identified, as well as approaches the Program can take to address those challenges. Broadly, the challenges and their respective approaches fall into three categories, as outlined below:

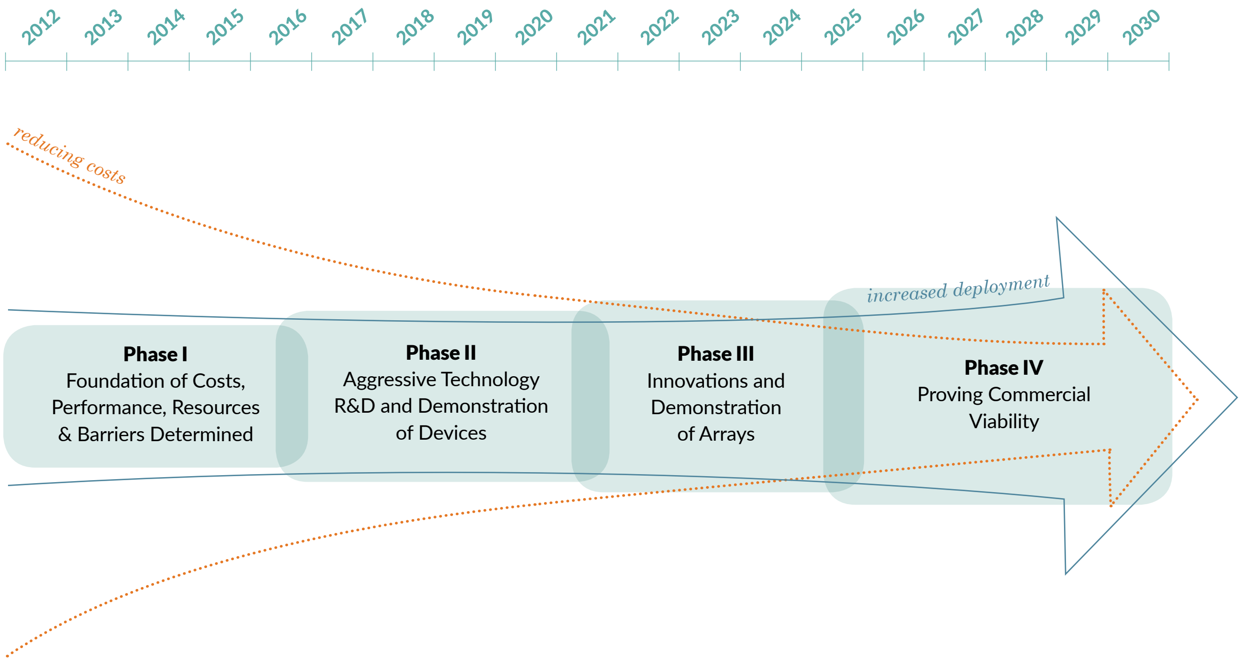
TECHNOLOGY MATURITY	DEPLOYMENT BARRIERS	MARKET DEVELOPMENT
• Testing infrastructure • Installation, grid integration, operations and maintenance • Array configuration • Design optimization • Evaluation metrics	• Regulatory concerns • Environmental effects • Availability of accurate unbiased information • Competing uses of ocean space • Deployment infrastructure	• Risk quantification • Resource characterization • Investor relations • Incentives and policy measures • Workforce development

An overview of draft MHK Program research, development, and demonstration (RD&D) phases to address challenges to meet the strategic goals follows. Note: These proposed RD&D phases are intended to summarize major objectives, and they do not represent all activities that would be planned/undertaken in these phases:

- Phase I (~2009-~2015) [Complete]: Complete critical foundational work to determine existing technology costs and performance, R&D needs, resource opportunities and deployment barriers
- Phase II (~2015-~2020) [Ongoing]: Aggressive technology innovation and demonstration of marine and hydrokinetic systems for multiple resource and market applications
- Phase III (~2020-~2025): Implement array-scale innovations and technologies with pilot-scale array demonstration projects
- Phase IV (~2025-~2030): Prove the commercial viability of marine and hydrokinetic technologies by supporting long-term utility-scale array demonstrations

A full description of all the challenges and targeted, phased approaches are available in a draft of the strategy that is currently open to public comment. The document can be accessed at go.usa.gov/x9eSC. Public comments will be accepted through February 28, 2017.

To facilitate work realizing this vision, the Program supports a strong RD&D project portfolio. The Program also leverages capabilities at DOE national laboratories to spur innovation in promising research areas, identify cost-reduction pathways, and build coordinated partnerships with other government agencies, including the military, that are breaking new ground for the industry.



Possible progression through planned RD&D phases

MARKET INCENTIVES

The MHK incentives offered in the United States are the Federal Production Tax Credit (PTC) and the Business Energy Investment Tax Credit (ITC). The section 45 PTC provides a tax credit of 1.2 cents per kilowatt-hour for MHK technologies. The credit was extended through December 31, 2016, for projects that are at least 150 kW in nameplate capacity. MHK facilities that began construction prior to January 1, 2017, can elect to take the section 48 ITC in lieu of the PTC. The ITC lets MHK projects opt for a tax credit equal to 30% of capital expenditures in lieu of the PTC. No new projects will be eligible for federal tax incentives unless Congress adopts a tax credit extension in 2017.

At the state level, MHK technologies are an eligible energy resource under numerous states' renewable portfolio standards and voluntary renewable energy goals. MHK technologies also benefit from state funding opportunities, such as the Alaska Energy Authority's Emerging Technology Fund and Renewable Energy Fund and the Oregon Wave Energy Trust.

PUBLIC FUNDING PROGRAMMES

Department of Energy Water Power Technologies Office Marine and Hydrokinetic Program:
Because MHK energy is an early stage market with limited incentives for investment, the Program has a clear role in expediting the development and demonstration of innovative MHK technologies. The Program makes investments that support key technology innovations, mitigate risks, and assist the private sector in creating a robust U.S. MHK industry by providing funding and technical assistance. Specifically, the Program focuses on supporting RD&D to reduce the cost of MHK technology and reduce deployment barriers:

- Reducing cost: Help develop and demonstrate MHK systems for early adopter markets (i.e. high cost, remote, or non-electric) to prove technologies and gain operational experience. Simultaneously, support the development of innovative technologies to achieve cost reductions that are necessary to enter the utility scale electricity markets (i.e. lower cost markets)
- Reducing deployment barriers: Support RD&D projects that proactively address important deployment barriers for the first generation of MHK projects, and over time increasingly focus on addressing barriers for utility-scale electricity markets

Given the high costs for early stage MHK technologies today, the Program intends to devote the majority of its effort toward supporting technology cost-reduction activities from now until 2030. Activities to identify and address deployment barriers (related to manufacturing supply-chain, port and shipping infrastructure, workforce, and siting/permitting issues) are also a critical secondary priority, and efforts focusing on these issues will increase as cost-reduction goals are achieved and deployment rates increase.
The Program's Fiscal Year (FY) 2016 annual budget for MHK RD&D was funded at $44.3 million—a 7% increase from FY 2015. Most of the funding in FY 2016 was directed toward technology advancement and demonstration.
Through competitive funding solicitations, or Funding Opportunity Announcements (FOAs), the Program identifies and funds qualified projects within specific topic areas and subtopics that support program objectives, depending on available funds. In evaluating all proposals for new energy developments or new adaptations of existing technology, the Program rigorously assesses whether individual applications clearly demonstrate that the proposed advances can reasonably lead to a reduction in the total cost of energy produced when compared to other energy technologies.
In FY 2016, the Program allocated $27.3 million of the $44.3 million to new FOAs for MHK research, development, and demonstration (RD&D) projects addressing key technical and market barriers to commercial deployment in the United States. Together, these projects will increase the power production and reliability of MHK devices and help gather valuable data on how deployed devices interact with the surrounding environment. The Program made the following awards to a variety of recipient types, including private industry and universities:

- **MHK Energy Conversion and Environmental Monitoring Technology Advancement:** In August 2016, 10 organizations were selected to receive more than $20 million for new research, development, and demonstration projects that advance and monitor MHK energy systems. Three demonstration projects will integrate next-generation MHK hardware and software technologies into system designs. Their effectiveness will be tested during full-scale, open-water deployments over one year. The projects selected that focused on environment will help reduce the time and cost associated with required environmental monitoring.
- **Wave Energy Test Facility:** In December 2016, up to $40 million, subject to appropriations, was awarded to design, permit, and construct an open-water, grid-connected national wave energy testing facility. The facility will be developed in Newport, Oregon, by the Northwest National Marine Renewable Energy Center at Oregon State University.

Other FY 2016 funding supported National Laboratory R&D (see research and development section below), Small Business Innovation Research Grants, Small Business Vouchers, and other Program operations.

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 present funding efforts focus on advancing technology development to harness MHK resources to ensure energy security and for powering U.S. Navy and Marine Corps assets both on- and off-shore. With FY16 funding of $12 million, ongoing support for wave, tidal, and current energy converter device development and testing will serve to meet the power capture needs of naval facilities in areas characterized by a full range of wave and current resource availability. System reliability, serviceability, and energy capture level improvements may bolster the availability of as-yet-untapped MHK energy that may either act as a supplement to more conventional fuel sources or serve to solely power particular systems. Funds were allocated for the Navy's Wave Energy Test Site in Hawaii and the University of Hawaii's Hawaii Natural Energy Institute and MHK development efforts at the University of Washington, Applied Physics Laboratory.

RESEARCH & DEVELOPMENT

NATIONAL LABORATORIES

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 Program partners with several of these important institutions to support R&D in MHK technologies.

Sandia National Laboratories (SNL): Through partnerships with several national laboratories and academic institutions, SNL is leading efforts in technology development, market acceleration, and reference model developments. SNL contributes to MHK technology in the following areas:

- Advanced non-linear controls, system identification and wave tank testing, open source code development, device and array optimization, and operational and extreme events simulation
- Design, analysis, and testing of hydrokinetic turbines; including application of novel measurement techniques (e.g., fiber Bragg grating (FBG) sensors for high-fidelity load measurements)
- Advanced materials development, such as novel coatings and composites
- Ocean wave modeling, resource assessment and characterization, and classification
- Measurement and modelling of tidal and river current flows
- Wave and tidal energy modelling to predict environmental effects of energy removal and inform optimal device spacing
- Modelling tools for MHK environmental impacts, such as mammal strike impact and acoustic generation and propagation

National Renewable Energy Laboratory (NREL): NREL's water power program leverages 35 years of experience developing renewable energy systems to research, evaluate, validate, optimize, and demonstrate innovative water power technologies. NREL conducts and supports research and development on MHK technologies in a wide range of areas, including:

- Design and Simulation—Application of renewable energy system experience to MHK technology development and open-source tool development
- Technology Validation and Optimization—Assessment of MHK systems and components performance and reliability in lab and open-water environments
- Resource Characterization and Maps—Measurement systems and simulation and visualization tools that accelerate MHK engineering and project development nergy and Market Analysis—Cost models and tools to evaluate the economic potential and impacts of MHK technologies and projects
- Grid Integration—Assess impacts and value of MHK generation on power systems, from small distribution systems to high-penetration interconnection

Pacific Northwest National Laboratory (PNNL): PNNL supports the Program through research, engineering, information aggregation and dissemination, resource assessment, characterization, and forecasting. The laboratory also participates in market analysis, planning, and coordination to overcome barriers for water power. PNNL operates the only facility dedicated to coastal sciences in the national laboratory system. Its unique Marine Sciences Laboratory is located on the

Olympic Peninsula in Washington. PNNL's specific efforts include:

- MHK environmental impacts research, international outreach, engagement, collaboration, and information sharing
- Tidal and current model development and validation
- MHK technology advancement through advanced materials and manufacturing reliability
- Wave resource assessment and characterization
- Monitoring tools, mitigation technologies, and methodologies
- Education outreach and information sharing
- Implement Annex IV under OES on behalf of the Program

Oak Ridge National Laboratory (ORNL): ORNL conducts research in support of the MHK Program's mission, including:

- Assessing the environmental effects of instream technology
- Advanced materials
- Manufacturing for cost reduction and design flexibility in water power technology
- Assessment of stream resources amenable to low-cost, low-impact development

R&D HIGHLIGHTS

In 2016, the Program supported a variety of activities to enable technology breakthroughs that "float all boats," benefitting numerous industry participants or having broad public benefits. Among its activities, the office supported initial device demonstrations to prove efficiency, reliability, and commercial viability and developed strategic partnerships to leverage and focus resources (i.e. military, international organizations, private industry). R&D activity generally falls into one of four categories: technology maturity, deployment barriers, market development, and cross-cutting approaches. Below are select R&D highlights from each category that occurred in 2016:

TECHNOLOGY MATURITY

Wave Energy Prize: In November, the Program announced AquaHarmonics as the winner of the Wave Energy Prize, demonstrating a five-fold improvement in WEC energy capture per characteristic cost, an achievement earning the team a $1.5 million grand prize. An 18-month design-build-test competition, the Wave Energy Prize focused on catalyzing the development of game-changing WECs that will ultimately reduce the cost of wave energy. Teams worked toward the ambitious yet achievable goal of doubling the efficiency of WEC devices over the state-of-the-art technology prior to the launch of the prize. CalWave Power Technologies and Waveswing America were awarded second and third place, respectively, with $500,000 and $250,000 in cash prizes.

The Wave Energy Prize was a catalyst for a technology leap, and the innovations accrued during the competition will drive down the cost of wave energy and help the sector achieve commercialization faster. Multiple technical innovations in the areas of controls, geometry, and survival strategies have resulted from the Prize. Some examples include adaptive sea state-to-sea state control; wave-to-wave control; power absorption in multiple degrees of freedom; optimized float shapes for energy absorption from a broad bandwidth of wave frequencies; survival strategies, such as submerging beneath the surface during extreme storms. But it's important to note that all the benefits of the Wave Energy Prize have yet to be realized. The technical advances made during this Prize competition will help developers accelerate the iterative learning process they face on the path toward commercialization. It is also the Program's hope that communities formed among investors, marine energy and engineering experts, and onlookers will accelerate the technical and financial capacity of developers. In addition, data from Prize testing will become publically accessible in November 2017—letting current and future technology developers benefit from the data collected in the Prize.

MHK Generator Technology Testing: In 2013, three entities were awarded $8 million to develop and demonstrate next-generation Power Take-Off (PTO) systems for MHK applications under the System Performance Advancement effort. In 2016, ABB, Inc., successfully built and tested one of the world's largest magnetically geared generators for direct-drive applications. The generator has been designed for low-speed, high-torque operation and provides increased reliability, overload operation and protection, controllability for peak power, and torque limiting. ABB partnered with Resolute Marine Energy to support the design and integration of the next generation PTO into Resolute's oscillating wave surge converter system.

Columbia Power Technologies, Inc., (CPwr) has completed design and fabrication of a novel, commercial-scale, direct-drive generator with a novel air-gap control system for wave energy converter devices. The PTO employs modular permanent magnet generator components with advanced power electronics to simplify transportability, operations and maintenance, and improve energy capture and reliability. These attributes are enabled by the following innovations:

- A flexible, non-rigid and low-cost generator frame as compared to conventional machines
- Reduction of rotor-stator air-gap to 4mm and consequently lower-cost electromagnetic design
- The ability to reduce the StingRAY's cost-of-energy by increasing generator diameter to much larger dimensions, while maintaining a small air gap

The PTO project aims to validate defined performance targets for this critical technology element. A successful demonstration of the 6.5m diameter permanent-magnet generator is expected to confirm the ability to further reduce cost of energy through air-gap reduction to 2mm or less on future systems. CPwr has commenced dry testing of the commercial-scale PTO on the 5-MW dynamometer at NREL's National Wind Technology Center (NWTC), leveraging decades of wind industry research and development experience, and will be completed in early 2017.

Ocean Renewable Power Company (ORPC) has completed trade studies for submersible generator designs and novel bearing concepts for integration with MHK systems. Generator trade studies have evaluated switched reluctance generator concepts against permanent magnet designs, and bearings development has focused on significantly reducing losses from driveline friction in tidal applications. ORPC has employed Rolls Royce Marine to fabricate a permanent magnet generator that allows for modular integration of ORPC's bearing concept. Testing will be completed in 2017 on a section of the TidGen® driveline to demonstrate PTO performance improvements.

Advanced Design Tools: In 2016, the Program and national laboratories performed research with the objective of improving performance, reliability, and survivability, while lowering the cost of energy. NREL and SNL worked on the following projects in 2016 to provide open-source simulation tools, develop extreme condition design methodologies, and advance control strategies:

- The Wave Energy Converter Simulator project continued development of an open-source design and analysis code (WEC-Sim) and performed experimental wave tank tests to develop validation data sets. Code development is continuing in 2017 and data sets will be made publically available.
- NREL and SNL developed a methodology for modelling WECs in extreme conditions that combines mid- and high-fidelity simulation methods to efficiently simulate and analyze the performance of WECs in extreme and survivability conditions. The WEC Design Response Toolbox (WDRT) was created to provide developers

with some of the tools needed to implement this methodology. WDRT is publically accessible for download at http://wec-sim.github.io/WDRT/index.html.

- SNL and NREL worked to advance WEC control strategies through two projects:
  - SNL completed extensive wave tank testing using advanced system identification methodologies. The models developed from this work will serve to improve the performance of future control strategies. Data from the wave tank testing is available on the MHK Data Repository (https://mhkdr.openei.org/).
  - NREL explored the feasibility of using advanced control strategies in conjunction with "active geometry" WECs that have the ability to change their geometry with changing wave conditions.

NNMREC's Advanced Laboratory and Field Arrays Project (ALFA): NNMREC is a multi-institution entity with a diverse funding base focused on R&D for marine renewables. The ALFA project conducted by NNMREC works to reduce the LCOE of MHK energy by leveraging research, development, and testing capabilities at Oregon State University, University of Washington, and the University of Alaska, Fairbanks. ALFA will accelerate the development of next-generation arrays of WEC and tidal energy conversion devices through a suite of lab- and field-focused R&D activities spanning a three-year performance period. These tasks include:

- Debris modelling, detection, and mitigation
- Autonomous monitoring and intervention
- Resource assessment and characterization for extreme conditions
- Robust models for design of offshore anchoring and mooring systems
- Performance enhancement for marine energy converter arrays
- Sampling technique evaluations for MHK biological monitoring

NNMREC's ALFA project is also developing a low cost semi-autonomous underwater vehicle (AUV) to assist with maintenance of MHK devices. The AUV will be capable of performing inspection, monitoring, and intervention, and it will have a lower cost than existing remotely operated underwater vehicles. In 2016, the second year of the ALFA project, NNMREC demonstrated the navigation station-keeping capabilities of the AUV in several ocean trials with low errors in mean position and heading (direction). In the third year of the ALFA project, autonomous mapping and intervention operations will be tested.

Metrics development: Well-developed, universal economic performance metrics let investors more confidently focus on promising technologies. The predominant metric for energy technologies at commercial scale is the levelized cost of energy (LCOE). But because LCOE estimation for devices at low technology readiness level (TRL) is prone to high uncertainties, it is important to identify other techno-economic performance metrics that are more suitable for the early stages of technology development. As such, technology performance levels (TPLs) have been introduced and refined as a techno-economic performance assessment metric for WEC technologies. Even at low TRLs, the TPL assessment is effective as it considers a wide range of WEC attributes that define the techno-economic performance potential when developed to higher TRL, and it highlights potential showstoppers at the earliest possible stage of WEC technology development. The TPL assessment methodology was revised in 2016 through a consistent application of the systems engineering approach. This approach led to the identification of a full set of stakeholder requirements and necessary WEC functions. The stakeholder requirements directly led to the assessment criteria for the updated TPL metric. For more information, visit go.usa.gov/x9MYg.

DEPLOYMENT BARRIERS

Environmental R&D: In 2016, the Program awarded seven new projects a total of $5.49 million to improve the technical performance and reduce costs associated with existing environmental monitoring technologies for use around MHK devices. These technologies are focused on monitoring marine organism interactions, noise produced by MHK devices, electromagnetic fields produced by subsea cables and MHK devices, benthic habitat monitoring and mapping, and the refinement of integrated instrumentation packages to monitor MHK devices more effectively.

Also in 2016, a number of existing projects made excellent progress. Five projects to develop new environmental monitoring technologies focused on the detection and classification of marine animals in the vicinity of MHK devices, measurement of noise produced by devices, automation of optical data processing, and the development of integrated instrumentation packages. Many projects performed prototype tests in tank settings and extended field trials, demonstrating the technical capabilities of the monitoring instruments. The Program had awarded $2.75 million in 2014 to support these projects.

Nine projects that focused on advancing the understanding of potential environmental effects from the deployment and operation of MHK devices either completely finished or are in the process of finishing. The projects included researching device-generated noise and its subsequent effects on marine megafauna, understanding interactions between fish and tidal turbines, developing and using models to predict strike occurrence, and assessing the potential effects electromagnetic fields may have on marine species. The Program awarded $2.4 million in 2013 to support these projects. The final reports from these projects will be made publically available on the Tethys database (https://tethys.pnnl.gov) once they are complete.

MARKET DEVELOPMENT

Market Analysis Efforts: In 2017, the Program will research the viability of non-utility scale electricity generation end uses and alternative markets or value streams, such as reverse osmosis desalinization for coastal urban water supply, micro-grids, forward operating military applications, remote islands, ocean and weather observation systems, shoreline protection and resilience applications, aquaculture, and data centers. This new effort builds off FY16 research into WEC-powered RO desalinization systems, which has yielded important metrics to focus future R&D activities, developed computational modules for design simulation, and produced an initial techno-economic assessment to understand market potential. By assessing early adopter markets of high value for MHK, their unique scale, and synergies with utility-scale generation, the Program's 2017 market study will identify the most competitive cost-of-energy markets for MHK. By the end of the year, a report will be developed outlining the most salient non-electric and off-grid electric market opportunities, the estimated market sizes, and the practicality of deploying existing technologies.

CROSS-CUTTING APPROACHES

Resource Model Refinement and Wave Classification: In 2016, the Program identified and published a list of locations where tidal and wave resources match electricity loads, as well as where local economics would be conducive to marine power. With that intelligence, the Program modelled wave and tidal regional sites along U.S. coasts. A wave classification scheme is also being developed using this information. The scheme uses peer-reviewed information to identify which variables are most important in making classifications. Throughout 2017, the Program will collect data from various wave and tidal sites to verify and validate models, modelling efforts, and the wave classification scheme, as well as adjust it when necessary. Feedback from the Marine Energy Council concerning tidal assessments have been heeded, and funding has been allocated to review the Program's analysis. In addition, other modelling efforts continue with high resolution grids for wave and tidal areas of interest, which will be added to the MHK Atlas (https://maps.nrel.gov/mhk-atlas/).

MHK Data Repository (MHKDR): Working with NREL, the Program launched the MHKDR website in March 2015. The repository houses all data collected using Program funds and serves as a data-sharing platform to help store and disseminate open-source data relevant to the design and development of marine energy technologies. Since then, 10 content models have been developed to help structure the data submitted to the MHKDDR, and more than 100 submissions from DOE-sponsored projects have been uploaded. The project data (subject to moratorium) is now accessible to the public and indexed on national search engines, such as Data.gov, resulting in thousands of downloads from users across the world. Transparency and open data are important to accelerate technology development and to avoid funding the same technology evolution by several different companies. It also helps to attract new players from related offshore and engineering sectors. The MHKDR provides an easy method for uploading data in a secure environment to help with the reporting requirements of national labs and industry awardees. Awardees who received U.S. public funding through financial assistance mechanisms are able to keep their data proprietary up to five years, after which it is to be made available to the public.

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

The development of comprehensive testing infrastructure is a strategic imperative for the Program to successfully address sector challenges, as outlined in the draft strategy. Test facilities offer diverse testing services addressing technical and nontechnical barriers of MHK commercialization. Prototype testing is essential to advance existing MHK technologies, validate performance against analytic models, and demonstrate compliance with applicable design standards. Testing mitigates the technical and financial risk of developing and deploying MHK energy devices, plants, technologies, and related products. By supporting the development of testing infrastructure, the Program ensures that many more prototypes from a diverse set of technology developers can be tested than if each technology developer had to carry the cost burden of developing, permitting, and installing its own test facility. As a result, promising technologies that could have failed due to insufficient funds have a chance to succeed.

Navy's Wave Energy Test Site (WETS): The U.S. Naval Facilities Engineering Command operates an ocean wave energy test site facility located at Marine Corps Base Hawaii in Oahu's Kaneohe Bay. The facility includes infrastructure to support offshore testing of a point absorber or oscillating water column device with up to a three-point mooring configuration. In 2015, construction was completed of two additional grid-connected test berths at 60-meter and 80-meter depths for 100 kW to 1 MW wave energy converters (WECs). The Navy also operates a grid-connected test berth at a depth of 30 meters.

Pacific Marine Energy Center (PMEC) – Wave and Current Test Facilities: Pacific Marine Energy Center (PMEC) is the marine energy converter testing facilities arm of the Northwest National Marine Renewable Energy Center (NNMREC). Just as the European Marine Energy Center has a variety of sites based on scale and technology, PMEC offers a range of test facility types. For wave energy testing, PMEC supports two operational test sites: the North Energy Test Site (NETS) off the coast of Newport, Oregon, and Lake Washington in Seattle, Washington. NETS has a mobile Ocean Sentinel test buoy that facilitates open-ocean, stand-alone testing of WEC devices with average power outputs up to 100 kW. Current turbines up to 10 kW power output can be tested at the Tanana River Test Site (TRTS) in Alaska.

Pacific Marine Energy Center - South Energy Test Site (PMEC-SETS) and the California Wave Energy Test Center (CalWave) – Wave Test Facilities (Under Development): In 2016, NNMREC and California Polytechnic State University continued developing preliminary designs and cost estimates for full scale, open-ocean, grid-connected wave energy test facilities, PMEC-SETS and CalWave respectively. PMEC-SETS is located off the coast of Newport, Oregon. CalWave has investigated and characterized several potential locations for a wave energy site offshore of Vandenberg Air Force Base in Southern California. Researchers continued preliminary design and cost estimates for a selected location and began the permitting process in 2016. At the end of 2016 the Program selected PMEC-SETS as the recipient of up to $40 million in federal funding, subject to appropriations, to design, permit, and construct the PMEC-SETS national wave energy testing facility. Following construction, PMEC-SETS will serve as a wave energy test facility for evaluating full-scale WEC device performance, environmental interactions, and survivability.

Southeast National Marine Renewable Energy Center (SNMREC) – Ocean Current Test Facility: SNMREC, operated by Florida Atlantic University, is working to advance research in open-ocean current systems by building the capability, infrastructure, and strategic partnerships necessary to support technology developers on the path to commercialization. In addition to a remarkable collection of Florida Current resource and biological data for MHK site selection and equipment design, the center offers onshore and offshore testing capabilities. Onshore, a 25-kW dynamometer provides drive train and generator performance evaluation with ocean current data emulated from field measurements. Offshore, developers can use towed testing or component testing with a 3 m, 25-kW horizontal axis research turbine and in-water rotor testing platform. Grid-connected, full-scale test berths are under development.

Hawaii National Marine Renewable Energy Center (HINMREC) – Wave Test Facility and Ocean Thermal Energy Conversion (OTEC): HINMREC's mission is to facilitate the development and commercialization of WEC devices and to assist the private sector with moving ocean thermal energy conversion systems beyond proof-of-concept to pre-commercialization. HINMREC supports the Navy in the operation of WETS, providing independent assessment of the power performance (i.e., power output as a function of wave environment) of pre-commercial WEC devices tested therein, while also evaluating their potential environmental impact by measuring acoustic emissions and performing ecological surveys in the ocean area surrounding moorings and along the submarine power cables connected to the electrical distribution system.

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 has two test berth locations, one at 6 m water depth and one at 11 m depth. The wave climate at the test site varies seasonally, with calmer seas in the summer compared to more energetic seas in the winter.

U.S. Army Corps of Engineers (USACE) Field Research Facility (FRF): The Field Research Facility is near the town of Duck, North Carolina. 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 10-person staff of computer specialists, technicians, and oceanographers are known for their ability to collect data, design experiments, and conduct research. 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. The research pier can serve as a cable conduit through the surf zone to locations on land.

Center for Ocean Renewable Energy (CORE): CORE, located in and around Durham, New Hampshire, was founded in 2008 and provides multiple-scale research, technology development and evaluation, education, and outreach for issues related to ocean renewable energy systems. CORE's physical infrastructure consists of the Chase Ocean Engineering (OE) Laboratory with wave/tow tank, engineering tank and water/wind tunnels, the General Sullivan Bridge tidal energy site, the UNH Pier and the AMAC/wave energy site. Mooring grids, historical environmental and survey data, and support vessels are available.

The University of Maine: The University of Maine has the ability to test at three different scales to support the development of new offshore renewable energy devices. Developed with over $20M of federal and State funding to support UMaine's own technology development effort for floating wind turbines, three test sites have been developed to qualify new technologies through 1/50 to 1/20 testing in a 100ft x 30ft x 15ft wave tank, intermediate scale testing (1/10 to 1/4) in a sheltered grid-connected offshore site off the Maine coast, and full-scale testing at an offshore test site located approximately 11 miles off the coast of Maine.

OPERATIONAL PROJECTS

Fred. Olsen: Fred. Olsen Autonomous Sea Power's wave energy converter, the BOLT Lifesaver, was installed at WETS on March 26, 2016. BOLT Lifesaver operates autonomously and operation has mainly been monitored and controlled from Fred. Olsen's headquarters in Oslo, Norway. Out of the 280 days installed in 2016, the device has been in power production 218 days, or 78% of the time, producing a total of 17.955 kWh at an average of 3.4 kW. Notably, the device has been in uninterrupted power production since July 19 (165 days). The current deployment expires in March 2017. Fred. Olsen is looking to further extend the deployment.

PLANNED DEPLOYMENTS

Northwest Energy Innovations (NWEI): NWEI's Azura™ is a multimode, "point absorber" wave energy device 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. With funding from the Program, NWEI will design, fabricate, and test a full scale Azura™ wave energy device to reduce the LCOE and demonstrate commercial viability at a deep water berth at U.S. Navy's WETS in Hawaii. The proposed testing will allow NWEI and its team to determine the energy capture matrix of a full scale device, resulting in a more accurate assessment of LCOE.

Ocean Energy (OE) USA: The OE Buoy, based on the oscillating water column principle, converts wave energy into useful mechanical energy using the principle that the air contained in the plenum chamber is pumped through an air turbine system by the wave action. This project will leverage lessons learned from three years of extensive scale model testing in Galway Bay, Ireland, that identified design opportunities to lower the cost of electricity and make these design improvements to the OE Buoy technology for a full scale deployment at WETS. The open water demonstration of the buoy will gather baseline performance data, gain operational experience, and identify further cost reduction opportunities for oscillating water column devices. Comprehensive LCOE validation data will also be generated during the 12-month deployment commencing in 2017.

Columbia Power Technologies: Columbia Power Technologies will conduct an open-ocean demonstration of a large-scale StingRAY at WETS in 2018 in a project co-sponsored by the DOE and Navy. The StingRAY is a hybrid design that benefits from the characteristics of both point absorbers and attenuators, significantly increasing energy capture, availability, and survivability. The StingRAY has a composite hull and two large-diameter, direct-drive permanent-magnet-generators and is intended for offshore, utility-scale wave farms. In early 2016, Columbia Power received a Statement of Feasibility from DNV GL for version 3.2 of the StingRAY design. The WETS StingRAY—resulting from 10 years of product development effort, five scaled-prototype tank-tests and three sea trials—will be deployed at the 80-m WETS berth and will demonstrate improvements offering lower-cost installation, operations and maintenance.

Verdant Power: Verdant's Kinetic Hydropower System (KHPS) is an axial flow current-capturing turbine system. Proposed is a highly integrated approach to the simultaneous design of a suitable mounting system and accompanying operational process for cost-effective installation, maintenance, and retrieval. Verdant and its partners will build on prior work to complete the nominal solution of a TriFrame (TF) that optimizes turbine spacing and structural requirements to allow for cost-effective Installation, Operation, and Maintenance (IO&M), including retrieval of three turbines with one on-water operation. Completing, and proving through testing, the final TF design and accompanying IO&M procedures, will be a major step in providing a commercial KHPS system. The design process, along with the specific results of economic tradeoff studies of single turbine versus tri-frame deployment concept and the investigation of applicability of these results to soft substrates, will be useful to other MHK developers.

Igiugig Village Council and Ocean Renewable Power Company: Igiugig Village, Alaska, has partnered with Ocean Renewable Power Company (ORPC) to develop the RivGen Power System, a submerged cross-flow river current turbine system. This project proposal uses a RivGen to demonstrate IO&M design improvements, including deployment and retrieval operations with minimal vessel support and no divers, and enhancements to make system components modular to simplify maintenance and more durable during operations. The project will implement, test (full-scale) and validate the system improvements which have been identified, designed, and analyzed. The project will reduce energy costs and offset diesel generation in remote locations. A reliable and durable RivGen Power System will provide a model for MHK project implementation using local equipment and resources that is replicable in Alaska and nationally.

Resolute Marine Energy: The Program has supported Resolute Marine Energy in the development of intelligent feedback and feed-forward control algorithms for use in its next-generation Oscillating Wave Surge Converter (OWSC). The control systems will first be tested on a reduced-scale version of RME's wave-powered desalination/electricity generation system in RME's land-based development center. Upon completion of these tests, RME will then deploy a full-scale system at Camp Rilea, Oregon, for approximately one year of ocean trials. During the Camp Rilea tests, RME will also be evaluating a novel deployment and retrieval system which utilizes logistic-over-the-shore technologies (LOTS) developed by the U.S. military services. The goals of this aspect of the Camp Rilea test program include improving safety, reducing downtime associated with repair and maintenance operations, and measuring the effects on costs.

OTHER RELEVANT NATIONAL ACTIVITIES

In November 2016, the Program hosted the **Wave Energy Prize Innovation Showcase** - the culmination of an 18-month design-build-test competition - at the Naval Surface Warfare Center, Carderock Division, in West Bethesda, Maryland. Nine finalist teams tested their 1/20-scale model wave energy converter (WEC) devices in the nation's most advanced wave-making facility—the Naval Surface Warfare Center's Maneuvering and Seakeeping Basin. Three teams were awarded with cash prizes totalling more than $2 million at the showcase. AquaHarmonics from Portland, Oregon, won the grand prize by demonstrating a five-fold improvement in wave energy capture per characteristic cost. The Wave Energy Prize was a catalyst for a technology leap to drive down the cost of wave energy and help the sector achieve commercialization faster.

In March 2016, the Water Power Technologies Office gathered more than 75 executive members from the Department of Energy, national laboratories, and the marine energy industry for the **Executive Summit on Marine and Hydrokinetic Research and Development** in Washington, D.C. Attendees learned about the DOE's MHK investments in the national laboratories and identified activities ripe for technology transfer. Attendees had the unique opportunity to hear first-hand about the important innovations in the MHK research community and DOE's Small Business Voucher Pilot program, as well as engage in a discussion about DOE's research and development priorities.

In April, Washington, D.C., hosted **Waterpower Week**, which brought three events under one roof: National Hydropower Association's Annual Conference, the International Marine Renewable Energy Conference (IMREC), and Marine Energy Technology Symposium. Representatives from DOE, the national laboratories, and the water power sector participated in the events. Supported by DOE, IMREC featured a Wave Energy Prize showcase where finalists displayed their different WEC technologies. DOE also hosted a workshop to help inform a Marine and Hydrokinetic energy strategic plan for the United States.

The United States deployed its first offshore wind farm off the coast of Rhode Island in 2016. With the commissioning of the Block Island Wind Farm by Deepwater Wind, renewable ocean energy is becoming a topic of great interest for other coastal states. The Bureau of Ocean Energy Management (BOEM) hosted the **California Ocean Renewable Energy Conference** in November 2016 at University of California, Davis. At the conference, NREL ocean renewable energy technologists met with colleagues from the sector to share information about California's offshore renewable energy resources and their technology status. Ocean wave and tidal energy topics included information on U.S. wave and tidal energy resources, global activities, technology types, R&D, and deployments. The conference held a panel session to discuss the human dimensions of the ocean renewable energy industry, which focused on potential jobs and economic development benefits from the use of ocean renewables in California. Additional information on the conference is available on the BOEM website at https://www.boem.gov/CORE_Conference/

In December 2016, the Department of Energy's Clean Energy Investment Center (CEIC) hosted its year-end **Laboratory-Investor Knowledge Series (LINKS)** in Menlo Park, California, at the SLAC National Accelerator Laboratory (SLAC). Nearly 40 participants representing the investment community (including venture capital firms and philanthropic organizations), the Department of Energy (DOE), and the White House were in attendance to highlight the anticipated release of the Laboratory Partnering Service (LPS) in January 2017, a new tool to facilitate access to and enable partnerships with DOE national laboratories. The event included a presentation on the U.S. wave and tidal ocean energy resources, the development status of these technologies, and a synopsis of the Wave Energy Prize competition results. Attendees were introduced to DOE's research and development initiatives to commercialize economically competitive wave and tidal energy technologies. For addition information on the meeting and the DOE Clean Energy Investment Center visit their website at: https://energy.gov/technologytransitions/us-department-energys-clean-energy-investment-center

06. WORLWIDE INSTALLED CAPACITY

The ocean energy sector is continuously growing at a global scale, but at different paces. Tidal currents technologies have been more rapid and are close towards the development and deployment of first arrays, wave energy projects are continuing to pre-commercial demonstration, and the first pilot projects on ocean thermal energy conversion and salinity gradient technologies are been developed. Technologies to exploit tidal range power are today the only ones to have reached commercialization stages.
Ocean energy technologies are largely at the prototype testing phase (with the exception of tidal range energy technologies). Despite the recent growth of installed capacity, there are many aspects that have to be addressed to bring the technology closed to the market.

``Key actors in the sector – device developers, project developers, component manufacturers, investors and government bodies – need to engage with technologies and with each other over the coming years and there are indications that this is happening in countries with an active role in ocean energy development.
‘..it is worth restating that Ocean Energy development is taking place because there is an urgent need to replace fossil fuel as a source of electricity generation, the oceans contain a massive source of potential energy, and that the development and deployment of the technologies associated with ocean energy, will support and synergise with wider moves to harness and protect ocean resources.

Ocean Energy Discussion Paper (2016), a contribution of the OES to the OECD study “The Future of the Ocean Economy: Exploring the prospects for emerging ocean industries to 2030”

BELGIUM

PROJECT	PLACE	RESOURCE	INSTALLED CAPACITY	STATUS AND REMARKS
Laminaria	Orkney, Scotland	Wave Power	100 kW	Consent authorized; deployment in 2017

CANADA

PROJECT	PLACE	RESOURCE	INSTALLED CAPACITY	STATUS AND REMARKS
Annapolis Royal	Nova Scotia	Tidal Range	20 MW	Operational since 1984
Cape Sharp Tidal Venture	FORCE Nova Scotia	Tidal Current	2 MW	2 MW installed in 2016; operational and grid connected
Cape Sharp Tidal Venture	FORCE Nova Scotia	Tidal Current	-	2 MW planned deployment in 2017
Black Tidal Power	FORCE Nova Scotia	Tidal Current	-	Planned deployment in 2017 – 5 MW total
Minas Tidal Limited Partnership	FORCE Nova Scotia	Tidal Current	-	Planned deployment in late 2017 – 4 MW total
Atlantis Operations Canada	FORCE Nova Scotia	Tidal Current	-	Planned deployment in 2018 – 4,5 MW total
DP Marine Energy	FORCE Nova Scotia	Tidal Current	-	Planned deployment in 2018 – 4,5 MW total
Mavi Innovations	Blind Channel Resort and Marina	Tidal Current	-	Planned deployment in late 2017
Water Wall Turbine	Dent Island, British Columbia	Tidal Current	500 kW	Deployment in 2016 – 500 kW total
Mermaid Power	Keats Island, British Columbia	Wave Power	11 kW	Operational; rated 11 kW at 32 inch waves
Idénergie	Various Parks Canada sites	River Current	3 kW	Installed for seasonal purposes; turbines removed for the winter
New Energy Corporation	Sagkeeng, Manitoba	River Current	25 kW	Deployment in mid 2017

CHINA

PROJECT	PLACE	RESOURCE	INSTALLED CAPACITY	STATUS AND REMARKS
Jiangxia Tidal Power Plant	Jiangxia, Zhejiang Province	Tidal Range	4,100 MW	Operational
LHD Tidal Current Energy Demonstration Project	Zhoushan, Zhejiang Province	Tidal Current	1 MW	Operational; total installed capacity is 3,4 MW
Zhairuoshan Tidal Energy Power Demonstration Station	Zhairuoshan Island, Zhejiang Province	Tidal Current	180 kW	Operational; 120 kW tidal current turbine + 60 kW tidal current turbine
Zhoushan Tidal Current Energy Demonstration Project	Zhoushan, Zhejiang Province	Tidal Current	450 kW	Consent authorized
Daishan Tidal Current Technology Demonstration Station	Zhoushan, Zhejiang Province	Tidal Current	600 kW	2×300 kW tidal current turbine installed
Zhaitang Island Hybrid Power Station	Zhaitang Island, Shandong Province	Tidal Current	300 kW	Demonstration project has been concluded
Shengshan Island Isolated Hybrid Power Demonstration Station	Shengshan Island, Zhejiang Province	Wave Power	525 kW	Operational: 300 kW wave energy, 150 kW wind turbines, 50 kW bioenergy, 25 kW solar thermal
GIEC Wanshan Island Isolated Hybrid Power Demonstration Station	Wanshan Island, Guangdong Province	Wave Power	700 kW	Installed: 300 kW wave energy, 100 kW wind turbines and 300 kW solar panels
CSIC710 Wanshan Wave Energy Demonstration Project	Wanshan Island, Guangdong Province	Wave Power	100 kW	Installed

DENMARK

PROJECT	PLACE	RESOURCE	INSTALLED CAPACITY	STATUS AND REMARKS
Wavepiston	DanWEC	Wave Power	12 kW	Installed
NEMOS	DanWEC NB	Wave Power	1 kW	Operational
CrestWING	Kattegat	Wave Power	30 kW	Consent authorized
Weptos	Lillebælt	Wave Power	6 kW	Consent authorized
Resen Waves	DanWEC NB	Wave Power	1 kW	Consent authorized
ExoWave	Hvide Sande havn	Wave Power	<1 kW	Consent authorized

FRANCE

PROJECT	PLACE	RESOURCE	INSTALLED CAPACITY	STATUS AND REMARKS
La Rance barrage	Saint-Malo	Tidal range	240 MW	Operational; Ongoing upgrade
Sabella D-10	Ushant, Fromveur race	Tidal Currents	250 kW	7 month operational, yet on maintenance/upgrade
Oceanquest	Paimpol Bréhat	Tidal Currents	1 MW	Consent authorized; Variable depths,low sensitivity to current orientation
Nepthyd	Raz Blanchard	Tidal Currents	5.6 MW	Construction/ installation; ALSTOM technology, 4 turbines, 20-year operation
Pampol-Bréhat	Paimpol Bréhat	Tidal Currents	2 MW	16m OpenHydro technology, 2 turbines, installed
MegaWattBlue	Ria d'Etel	River Currents	250 kW	4m diameter; single turbine swiveling deployment

IRELAND

PROJECT	PLACE	RESOURCE	INSTALLED CAPACITY	STATUS AND REMARKS
Westwave	Killard	Wave Power	5 MW	Planning permissions

ITALY

PROJECT	PLACE	RESOURCE	INSTALLED CAPACITY	STATUS AND REMARKS
GEM	Strait of Messina	Tidal Currents	200 kW	Consent authorized; Planned 2018
KOBOLD	Strait of Messina	Tidal Currents	60 kW	Deployed in 2000
ISWEC	Pantelleria, Sicily	Wave Power	100 kW	Deployed in2016
H24 WEC	Marina di Pisa	Wave Power	50 kW	Deployed in 2015
REWEC-3	Civitavecchia Harbour, Civitavecchia	Wave Power	No	Operating in 2017

KOREA

PROJECT	PLACE	RESOURCE	INSTALLED CAPACITY	STATUS AND REMARKS
Yongsoo WEC / OWC	Jeju	Wave Power	2 x 250 kW	Started operation in 2017
INWave WEC / Onshore-based disk buoy	Jeju	Wave Power	135 kW	In operation since 2015
KRISO Floating WEC / Pendulum Utilizing Standing Waves	Jeju	Wave Power	300 kW	Consent authorized; planned to deploy in 2018
Hwa Jin WEC / Heaving semi-spheres with hinged arm	Uljin	Wave Power	30 kW	Operated in 2016
KIOST TEC/Active-controlled HAT	Uldolmok	Tudal Currents	200 kW	Planned to operate in 2017
SUPRC OTEC / Closed cycle	Goseong-gun	OTEC	20 kW	Started operation in 2013
SUPRC H-OTEC / hybrid OTEC	Goseong-gun	OTEC	200 kW	Installed; utilizing additional heat source from wood-chip gasification power plant
SUPRC MW OTEC / Closed cycle	Goseong-gun	OTEC	1 MW	Consent authorized; planned to operate the plant in Goseong in 2018 and then to move to Kiribati in 2019

MONACO

PROJECT	PLACE	RESOURCE	INSTALLED CAPACITY	STATUS AND REMARKS
Monaco Sea Water Heat Pumps	Monaco	Temperature (OTEC principle)	60/70 MW	75 Operational projects; 60 MW for cold production and 70 MW for heat production

MEXICO

PROJECT	PLACE	RESOURCE	INSTALLED CAPACITY	STATUS AND REMARKS
WEC device Exclusive High-Tech (DINA)-UNAM	Ensenada, Baja California	Wave Power	100-200 kW	Consent authorized; under development for its test at an open sea site.

NEW ZEALAND

PROJECT	PLACE	RESOURCE	INSTALLED CAPACITY	STATUS AND REMARKS
AZURA Wave	Hawaii	Wave Power	20 kW	Installed
Vennell Marsden	Otago	Tidal Currents	n/a	Array design technology; conceptual stage

NETHERLANDS

PROJECT	PLACE	RESOURCE	INSTALLED CAPACITY	STATUS AND REMARKS
Tocardo tidal turbines	Eastern Scheldt barrier	Tidal currents	1250 kW	Operational; Tocardo T2 turbines
Tidal Test Centre	Den Oever	Tidal currents	300 kW	Operational; Tocardo T2 turbines
Pentair fairbanks Nijhuis	Grevelingen barrier	Tidal currents	1000 kW	Planned for 2017; Part of the planned TTC (Tidal Test Centre)
Bluetec	Texel Island	Tidal/ free flow	100 kW	Operational; Tocardo T2 turbine (1)
REDstack	Afsluitdijk	Salinity	4-50 kW	Operational; Pilot & Test site

PORTUGAL

PROJECT	PLACE	RESOURCE	INSTALLED CAPACITY	STATUS AND REMARKS
Pico Plant	Azores, Pico	Wave Power	400 kW	Operational since 2007
AW-Energy/Waveroller	Peniche	Wave Power	350 kW	350 kW consented and deployment planned for 2017; 1 MW consented
Bombora Wave Power	Peniche	Wave Power	-	Planned; preparation of consenting phase submission

SPAIN

PROJECT	PLACE	RESOURCE	INSTALLED CAPACITY	STATUS AND REMARKS
Mutriku wave power plant by EVE	Mutriku, Basque Country	Wave Power	296 kW	Operational; more than 1.3 GWh produced during 5 years of operation
MARMOK-A-5 by Oceantec	BiMEP, Basque Country	Wave Power	30 kW	Under testing -Floating OWC device
UNDIGEN+ by Wedge Global	PLOCAN, Canary Islands	Wave Power	200 kW	Under testing since 01/2014 -Direct Drive Technology
Butterfly by Rotary Wave	Valencia	Wave Power	7 kW	Decommisioned; grid-connected device expected in 2017
WIP10+ by EnerOCEAN	PLOCAN, Canary Islands	Wave Power	TBD	Consent authorized; in combination with Offshore Wind

SWEDEN

PROJECT	PLACE	RESOURCE	INSTALLED CAPACITY	STATUS AND REMARKS
Sotenäs/point absorber	Sotenäs, Sweden	Wave Power	3 MW	Operational
The Lysekil wave energy research test site	Lysekil, Sweden	Wave Power	200 kW	Operational
Söderfors	Söderfors/Dalälven, Sweden	River/Tidal Currents	7,5 kW	Operational

UNITED KINGDOM

PROJECT	PLACE	RESOURCE	INSTALLED CAPACITY	STATUS AND REMARKS
Nova Innovation M100	Shetland	Tidal Currents	2 x 100 kW	Fixed horizontal axis turbine
Andritz Hydro Hammerfest	MeyGen, Scotland	Tidal Currents	2 x 1.5 MW	Fixed horizontal axis turbine

UNITED STATES OF AMERICA

PROJECT	PLACE	RESOURCE	INSTALLED CAPACITY	STATUS AND REMARKS
Fred.Olsen Autonomous Sea Power/ BOLT Lifesaver	WETS, Kaneohe Bay, Hawaii	Wave Power	30 kW	Operational; 17.9 MWh energy produced, 165 days of uninterrupted power production as of end 2016
Northwest Energy Innovations/ Azura	WETS, Kaneohe Bay, Hawaii	Wave Power	1 MW	Planned project with secured berth at an established test site; MW-scale device in development; deployment planned for 2019
Ocean Energy (OE) USA/OE Buoy	WETS, Kaneohe Bay, Hawaii	Wave Power	500 kW	Deployment at the 60m berth at WETS planned for fall / winter of 2017.
Columbia Power Technologies/ StingRAY	WETS, Kaneohe Bay, Hawaii	Wave Power	140 kW	Planned project with secured berth at Nave WETS test site
Resolute Marine Energy/ SurgeWEC™	Camp Rilea, Oregon	Wave Power	50 kW	Planned project with secured berth at an established test site
Verdant/ TriFrame Mounting Design	Roosevelt Island, New York	Tidal/River Currents	105 kW	Planned project with secured permit for testing at company leased site
Igiugig Village Council & Ocean Renewable Power	Igiugig, Alaska	River Currents	40 kW	Planned project with secured permit for testing at company leased site

APPENDICES

Appendix 1

THE ROLE OF THE IEA

What is the International Energy Agency (IEA)?

The 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 nonmember countries, especially major producers and consumers, to find solutions to shared energy and environmental concerns.

For more information on the IEA, see the Frequently Asked Questions.

What is an IEA Technology Collaboration Programme?

Technology Collaboration Programmes (TCPs) are independent, international groups of experts that enable governments and industries from around the world to lead programmes and projects on a wide range of energy technologies and related issues. TCPs currently cover topics related to:

- efficient end-use (buildings, electricity, industry, transport)
- cleaner fossil fuels (greenhouse-gas mitigation, extraction, supply, transformation)
- renewable energy and hydrogen (technologies and policies for deployment)
- cross-cutting issues (modelling, technology transfer, project financing)
- fusion power (safety, physics, materials, technologies).

The 6000 experts in the TCPs work to advance the research, development and commercialisation of energy technologies. The scope and strategy of each TCP is in keeping with the IEA Shared Goals of energy security, environmental protection and economic growth, as well as engagement worldwide.

What is the role of the IEA in the TCPs?

The IEA provides the framework for collaboration through TCPs, which is known as the **IEA Framework for International Technology Co-operation**.

This sets out the minimum requirements for TCPs and outlines the principal responsibilities of TCP participants and the various IEA bodies involved with TCPs. It is a legal structure that is designed to simplify international cooperation between national entities, business and industry. It also includes important information about participation and reporting requirements.

The IEA Secretariat provides guidance, advice and support by acting as conduit between TCPs and policy makers, and by promoting TCP outcomes where possible. The IEA also provides legal advice in relation to processes, procedures and the legal structure of TCPs.

Appendix 2

MEMBERSHIP OF THE EXECUTIVE COMMITTEE

CABINET 2016

CHAIRMAN
Mr. José Luis Villate
TECNALIA
Spain

VICE-CHAIR
Dr. Keyyong Hong
KORDI
Korea

VICE-CHAIR
Mr. Henry Jeffrey
The University of Edinburgh
United Kingdom

SECRETARY
Dr. Ana Brito e Melo
WavEC
Portugal

CABINET 2017

CHAIRMAN
Mr. Henry Jeffrey
The University of Edinburgh
United Kingdom

VICE-CHAIR
Mr. José Luis Villate
TECNALIA
Spain

VICE-CHAIR
Dr. Alison LaBonte
Department of Energy
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. Xia Dengwen National Ocean Technology Center	Mr. Lin Cui 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	Yann-Hervé De Roeck France Energies Marines	Kelly Cayocca France Energies Marines
Germany	Mr. Matthias Erdmann Federal Ministry for the Environment, Nature Conservation and Nuclear Safety	Mr. Jochen Bard Fraunhofer Institute for Wind Energy and Energy System Technology IWES
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	
Italy	Mr. Luca Benedetti Gestore dei Servizi Energetici (GSE)	

Japan	Dr. Yasuyuki Ikegami Institute of Ocean Energy, Saga University	Dr. Shuichi Nagata Institute of Ocean Energy, Saga University
Korea	Dr. Lae-Hyung Hong Ministry of Land, Transport and Maritime Affairs	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. José Luis Villate TECNALIA
Sweden	Ms. Maria Olsson Swedish Energy Agency	
UK	Mr. Trevor Raggatt Department of Energy and Climate Change	Mr. Henry Jeffrey The University of Edinburgh
USA	Dr. Alison LaBonte U.S. Department of Energy	Dr. Robert Thresher National Wind Technology Center

Appendix 3

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

NEXT EXCO MEETINGS

MEETING	DATE	LOCAL	COUNTRY
32	10 – 11 April 2017	Monaco	MONACO
33	November 2017	Chennai	INDIA

Appendix 4

COMPLETED PROJECTS

NAME	Annex II Development of Recommended Practices for Testing and Evaluating Ocean Energy Systems
OBJECTIVE	The objective of this Annex was to develop recommended practices for testing and evaluating ocean energy systems (wave and marine currents). There are a number of different resource types within ocean energy systems (including waves, tidal range, tidal and ocean currents, salinity gradients, OTEC and hydrothermal vents) and several different approaches to extracting energy from each resource type. The present lack of technology convergence creates difficulty in comparing systems. Annex II attempted to address this issue by providing guidelines, with the intent of laying the groundwork for the future establishment of standards and protocols, for theoretical, model and pro¬totype testing, preliminary cost assessments and the presentation of results.
OPERATING AGENT	Dr. Kim Nielsen, Ramboll – Denmark
DURATION	The Annex was set up in 2001 to address laboratory testing and, in 2006, the Executive Committee agreed to extend the Annex to address prototype testing. The Annex was concluded in March 2011.
REPORTS	***Development of Recommended Practices for Testing and Evaluating Ocean Energy Systems, Summary Report*** K. Nielsen (2010) ***Generic and Site-Specific Wave Data*** K. Nielsen and T. Pontes (2010) ***Guidelines for the Development & Testing of Wave Energy Systems*** B. Holmes (2010) ***Guidelines for the design Basis of Marine Energy Converters*** P. Davies (2009) ***Guidance for Assessing Tidal Current Energy Resources*** Cornett (2008) ***Tidal Energy Development Protocol*** S. Bahaj, L. Blunden and A. A. Anwar (2008) ***Preliminary Wave Energy Device Performance Protocol*** G. Smith and J. Taylor (2007) ***Preliminary Tidal-current Energy Device Performance Protocol*** S. J. Couch and H. Jeffrey (2007) All reports are available at www.ocean-energy-systems.org

NAME	Annex III Integration of Ocean Energy Plants into Distribution and Transmission Electrical Grids
OBJECTIVE	The overall aim of this Annex is to provide a forum for enabling co-operative research activities related to integration of wave and tidal current power plants into electrical grids.
OPERATING AGENT	Dr. Gouri Bhuyan, Powertech Labs – Canada
DURATION	This Annex was commissioned in 2008 and was concluded in March 2011
REPORTS	***Potential Opportunities and Differences Associated with Integration of Ocean Wave and Marine Current Energy Plants in Comparison to Wind Energy*** J. Khan, G. Bhuyan and A. Moshref (2009) ***Key Features and Identification of Needed Improvements to Existing Interconnection Guidelines for Facilitating Integration of Ocean Energy Pilot Projects*** J. Khan, G. Bhuyan, and A. Moshref (2009) ***Dynamic characteristics of wave and tidal energy converters & a recommended structure for development of a generic model for grid connection*** D. O' Sullivan, D. Mollaghan, A.Blavette and R.Alcorn (2010) ***Integrating Wave and Tidal Current Power: Case Studies through Modelling and Simulation*** M. S. Múgica, F. S. Fernandez , J. L. Mendia , J. Khan, D. Leon, S. Arabi, A. Moshref, G. Bhuyan, A. Blavette, D. O'Sullivan, R. Alcorn (2011) All reports are available at www.ocean-energy-systems.org

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OCEAN ENERGY SYSTEMS

Energy Technology Network

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