ANNUAL REPORT

OCEAN ENERGY SYSTEMS

2015

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An IEA Technology Initiative

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CONTENTS

CHAIRMAN'S MESSAGE

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

Renewable energy sources from the ocean will be indispensable actors for a long-term clean energy mix, contributing to ensure a world-wide energy supply near the point of local use.

Ocean Energy is still in its early stages of development and its contribution to global energy production is not highly significant yet. Nevertheless, the resource is abundant and well distributed around the world, in many cases close to high energy demand in coastal areas. Technologies to harness ocean energy are not mature enough, with some reliability and survivability problems, leading to high costs of energy in comparison to other sources. However, renewable energy sources from the ocean will be indispensable actors for a long-term clean energy mix, contributing to ensure a world-wide energy supply near the point of local use.

Ocean Energy is therefore facing a dilemma: how to fund technological development and first deployments at sea oriented to gain experience, improve performance, limit risks and finally reduce costs in a challenging long-term scenario. The participation of public bodies committed to a clean energy future using indigenous sources is essential to help solve this dilemma. It can bridge the gap between a promising present and a profitable future. I am very happy to see this commitment reflected in the country summaries of this annual report and I would particularly like to thank the contribution of US DoE, Wave Energy Scotland, Nagasaki Marine Industry Cluster Promotion Association, the European Commission and the Inter-American Development Bank addressing a set of questions that the reader can find in Chapter 4.

As stated before, high energy costs are probably the main drawback for the penetration of ocean energy in the energy mix. I would therefore like to highlight the Cost of Energy report produced by the OES as one of our main outcomes in 2015. This report provides an authoritative view on what cost reductions are feasible for the next future. The OES is continuing this task with an international technology roadmap, expected to be published in the first half of 2016, which will identify priority focus areas and investments to accelerate ocean energy technology development, allowing cost reductions to be realised.

Other relevant challenges faced by Ocean Energy are those connected to environmental and consenting issues. Although Ocean Energy must be considered as a positive contributor to global climate change actions, local environmental aspects have to be tackled when a particular project is defined and a long consenting process might be necessary. The OES is aware of this situation and is currently working on two tasks dealing with these topics. On one hand, Annex IV provides access to knowledge and information related to research, monitoring, and evaluation of the environmental effects of offshore renewable energy projects. The main tool implemented is *Tethys*, the online knowledge management system which supports Annex IV data and is expected to continue expanding. On the other hand, in task 8, the OES is collecting inputs from all OES members providing a coherent overview of the consenting processes: Marine Spatial Planning and site selection, regulatory issues, environmental impact assessment requirements, consultation and challenges to the consenting process.

I am convinced that the OES is playing a significant role in ocean energy development and we want to continue supporting this emerging sector over the next few years. To that end, in its latest Executive Committee meeting in November 2015, the OES decided to request the IEA to grant a 5-year extension of its current mandate, due to finish in 2017. Thanks to the commitment and support of all current OES members, and newcomers such as India and the European Commission, I am sure that this extension will be approved and the OES will continue working for ocean energy in 2017 and beyond.

Please enjoy this OES annual report, briefly presented by Ana Brito e Melo, OES Executive Secretary, in the next section.

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 under the International Energy Agency (IEA).*
This Annual Report presents an overview of the activities undertaken within OES in 2015.

INTRODUCTION

In 2015 the Executive Committee (ExCo) of the Ocean Energy Systems (OES) unanimously agreed to request the IEA to extend its mandate for a 4th 5-year term. Its present term will end on 28 February 2017. As part of the request, in late 2015, the OES commissioned an external expert to assist the ExCo in the preparation of a 4th Term Strategic Plan (2017-2021), which should be submitted in 2016 to the IEA Committee on Energy Research and Technology (CERT).

The OES 2015 membership remained steady at 23 (with Australia inactive during 2015). This membership, from Africa, Asia, the Americas, Europe and Oceania, provides a broad international base of experience and knowledge. Information sharing and collaboration on a wide range of research and development projects is therefore possible, aiding in our efforts to overcome technical and other challenges to advance the sustainable development of ocean energy worldwide and so contribute to the mitigation of climate change.

National governments appoint a Contracting Party to represent the country in the Executive Committee and there is a diversified representation of interests: governmental departments, utilities, universities and research organizations, energy agencies and industry associations. By information sharing and collaborative activities, participants gain an international perspective on ocean energy issues, opportunities and present challenges.

This Executive Summary provides an introduction to, and brief summary of, the 2015 OES Annual Report. It synthesizes progress with the OES collaborative activities and outlines the political initiatives and demonstration projects worldwide presented by each OES member country.

INTERVIEWS TO ORGANISATIONS FUNDING OCEAN ENERGY

As in previous years this Annual Report presents a summary from each OES member on their national programme activities. Further, a contribution by acknowledged experts from funding organisations is included. Representatives from five organisations funding ocean energy projects (**US DOE**, **Wave Energy Scotland**, **Nagasaki Marine Industry Cluster Promotion Association**, **the European Commission** and the **Inter-American Development Bank**) were invited to respond to four questions about funding approaches to ocean energy projects.

OVERVIEW OF OES COLLABORATIVE ACTIVITIES

The OES held two ExCo Meetings in 2015: The 28th and 29th meetings were convened in Kassel, Germany (12 – 13 May 2015), and Cancun, Mexico (11 – 12 November 2015).

Membership of the OES involves a commitment to national participation in certain collaborative research activities. Some of these research projects generally have duration of a number of years and are led by an '*Operating Agent*' from a member country, responsible for coordinating each project and reporting on progress to the ExCo. Under the OES nomenclature these research projects are defined as 'Annexes' to the work programme and are initiated whenever three contracting parties support a proposal and sufficient funding is raised.

The ExCo has also introduced some shorter term projects (approximately 1 year duration) funded by the Common Fund and based on a tender procedure. They can be conducted by a group of members and may include participation of external experts invited by the Delegates. In 2015, OES participants worked on the folllowing specific research topics:

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. Tethys, the online knowledge management system which supports Annex IV material, continued to expand and to increase user interactions.

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. To this end, Annex V has been sponsoring workshops, bringing international experts together to exchange data that can be used to develop an assessment of the fundamental knowledge of ocean energy.

TASK 6 Worldwide Web GIS Database for Ocean Energy – interactive web based GIS mapping application launched in 2014 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 – This project was set out to deliver the assessment of a credible 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.

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.

TASK 9 International Ocean Energy Technology Roadmap - in line with the IEA own technology roadmapping work, this project was initiated in 2015 and will be concluded in 2016. The overall objective of the ocean energy technology roadmap is to achieve LCOE targets within the ocean energy sector. This requires a special focus on two key areas: Reliability Improvement and Performance Improvement.

Further, a number of new proposals for R&D projects on topics of common interest to participants have been discussed by the ExCo, and a few proposals are under development to be discussed in 2016 and eventually approved during the year, including:

- Investigation and Evaluation of OTEC Resource (submitted by Japan)
- Ocean Renewable Energy for Island Electrification (submitted by Singapore)
- Best Practice for International Open Water Test Centres (submitted by UK)

- Wave Energy Modelling Verification and Validation (submitted by Denmark)
- Tidal Current Energy Modelling Verification and Validation (submitted by Singapore)
- Performance of Mooring Systems for Ocean Energy Systems (submitted by Denmark)
- International Assessment of Technology Performance Level (TPL) and Technology Readiness Level (TRL), (submitted by USA & Denmark)

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.**

KEY ACHIEVEMENTS BY THE OES IN 2015

- Annex IV continued to collect information on new wave and tidal projects and ongoing research studies. This information is accessed from *Tethys*, which currently includes 80 project sites and 57 research studies.

- Annex IV partnered with National Environmental Research Council to host a workshop at Ocean Business in Southampton, UK, on 16 April 2015 and partnered with the European Wave and Tidal Energy Conference (EWTEC), in September 2015, in Nantes, France, to enhance participation in the environmental track and increase the variety of papers presented. During the European Wave and Tidal Energy Conference, Annex IV hosted a workshop on 8 September 2015 to brief the international marine renewable energy community on the Annex IV State of the Science Report.

- Three webinars were held under Annex IV in 2015, each bringing together between 55 and 100 people online to listen to recent research results and plans.

- A draft of the State of the Science of environmental impacts of marine renewable energy report was prepared during 2015 and it is anticipated that that final report will be released in April 2016.

- The OES continues to develop a suite of information dissemination tools assisting the OES in becoming a leading authority on ocean energy; a Linkedin group "Ocean Energy Systems" was launched in 2015.

- A new project was initiated in 2015, "*International Ocean Energy Technology Roadmap*", including in a first stage the update of the OES International Vision for Ocean Energy.

- In February 2015, a workshop entitled "Designing for Reliability of Wave and Current Marine Energy Converters" was organized in Lisbon, Portugal, hosted by the Portuguese non-profit association WavEC. A fourth workshop on energy policies is being planned for May 2016 in Sweden.

- OES participated in the IRENA workshop "Island Energy Transitions: Pathways for Accelerated Uptake of Renewables", 22-24 June 2015, Martinique; following this event, the OES is considering to develop a new project on the topic "Ocean Renewable Energy for Island Electrification".

- The Report "*International Levelised Cost of Energy (LCOE) for Ocean Energy Technologies*", an analysis of the development pathway and Levelised Cost Of Energy trajectories of wave, tidal and OTEC technologies, was published in May 2015.

- OES contributed to the OECD project on the Future of the Ocean Economy with the preparation of the report "Ocean Energy Discussion Paper" examining the prospects and potential of the ocean energy sector.

OCEAN ENERGY POLICY

There is policy support for ocean energy in several forms in the OES member countries (see Table 1): market incentives, roadmapping initiatives and national maritime or energy strategies including ocean energy; legislation for improving licensing arrangements for ocean energy projects and to promote national planning; governmental funding from basic research to sea testing infrastructures.

Several political initiatives were reported by the member countries during 2015:

Korea established a strategic plan for 2015-2025, in which the main objective for ocean energy is to set up a relevant R&D support programme.

In **China**, the Government has been developing the "Renewable Energy Development Plan (2016-2020)", including the "Ocean Energy Development Strategy".

The "Partnership for Wave Power", created by **Danish developers**, published in 2015 a set of roadmaps for development of wave energy with support from the Danish Energy Agency and a new law for the use of marine space has circulated for comments at the end of 2015.

In **Sweden,** the Government completed a national maritime strategy, which has identified areas where actions are needed in order to promote a sustainable development in the Swedish maritime sector, including ocean energy. 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. The aim is to strengthen the research and development and increase the cooperation between academia and industry.

In **Canada**, at the federal level, the Department of Natural Resources Canada continues to take a lead role towards the development of a policy framework for administering marine renewable energy activities in the federal offshore.

The Government of **Nova Scotia** approved new legislation for a licensing and permitting system that assures that marine renewable energy projects are developed in a manner that respects the environment and the interests of local communities. Further, the new Electricity Plan for Nova Scotia, released in November 2015, replaced guaranteed Feed-in Tariffs (FITs) with a competitive process for renewable energy technologies.

In **UK**, on a national level, DECCs Energy Innovation Policy team has been working on an updated Technology Innovation Needs Assessment (TINA) for wave and tidal energy due to be published in 2016. This will enable the government to make effective decisions regarding how the wave and tidal stream sectors should be supported in future. Further, the Scottish Government remains committed to the continued development of a successful marine renewables energy industry in Scotland and to date, the Renewable Energy Investment Fund (REIF) has invested £37.1 million in marine energy projects with further investments planned. Wave Energy Scotland (WES) committed in 2015 over £10 million through a series of strategically targeted innovation projects and research activities.

In **USA**, the Water Power Program supported a strong research, development and demonstration (RD&D) project portfolio. The budget allocated for the US Department of Energy Water Power Program in 2015 was the highest on the Program's history. Several key pieces of US federal legislation that would help to advance the marine energy industry are currently under consideration.

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 pemium	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	UD	x	x	x
China			x	x					UD		x	x	x
Denmark		x			x				x	x	x		
Germany			x	x							x		
Ireland	x	x	x	UD	x				x	UD	x	x	x
Italy	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			
Norway				x			x		x		x		
New Zealand			x	x					P				
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			x		x		x	x	
United Kingdom	x		x	x	x	x			x	x	x	x	x
USA			x	x					x	UD	x	x	x

UD: Under Development

TABLE 2: OPEN SEA TEST SITES

COUNTRY	TEST SITE	LOCATION	GRID CONNECTION	STATUS
CANADA	Fundy Ocean Research Centre for Energy (FORCE) – In-stream Tidal Energy	Minas Passage, Nova Scotia	Yes (64 MW)	Operational
	Canadian Hydrokinetic Turbine Test Centre (CHTTC) – River Current Energy	Winnipeg River, Manitoba	Yes	Operational
	Wave Energy Research Centre	Lord's Cove, Burin Peninsula, Newfoundland & Labrador	No	Operational
CHINA	National small scale test site	Weihai, Shandong	Yes	Under development
	National tidal energy full scale test site	Zhoushan, Zhejiang	Yes	Under development
	National wave energy full scale test site	Wanshan, Guangdong	Yes	Planned
DENMARK	DanWEC	Hanstholm	No	Two wave and current Datawell buoys
IRELAND	National quarter scale Test Site	Galway	Yes	Operational
	Atlantic Marine Energy Test Site	Belmullet	Planned	Planned
ITALY	GEM	Strait of Messina	Yes (200 kW)	Planned 2016
	ISWEC	Pantelleria (Sicily)	Yes (100 kW)	Planned 2016
	KOBOLD	Strait of Messina	Yes (60 kW)	Deployed 2000
KOREA	Yongsoo WEC Test Bed	Jeju	Yes	Planned
	Uldolmok TEC Test Bed	Jindo	Yes	Planned
NETHERLANDS	Bluetec-Texel	Texel – Island (floating device)	Yes	Operating since end 2015
	Tocardo-Huisman	Oosterschelde Barrier	Yes	Operating since summer 2015
	REDstack Blue Energy	Afsluitdijk	No	End 2014
	Tocardo	Den Oever	No	2008
	Tidal Testcentrum	Grevelingen Barrier	No	Planned
NEW ZEALAND	NZ-MEC	Wellington	-	Planned
NORWAY	Runde Environmental Centre (REC)	Runde Island, Norwegian west coast	Yes	Operational
PORTUGAL	OceanPlug	São Pedro de Moel	To Be Determined	Existing
SINGAPORE	REIDS-Offshore (TMEC)	Southern Islands	To Be Determined	Planned-2017
	Sentosa Tidal Test Bed	Sentosa Boardwalk	Planned Up to 50kW	Existing
	TMFT Marine RE Test Bed	Tanah Merah Ferry Terminal	No	Existing
SPAIN	Bimep	Armintza, Basque Country	Yes (20MW)	Operating
	Mutriku Wave Power Plant	Mutriku, Basque Country	Yes	Operating
	PLOCAN	Gran Canaria (Canary Islands)	Expected by end 2016	Operating
SWEDEN	Lysekil wave power research site	Lysekil	Yes	Operating
	Söderfors research site	Söderfors/Dalälven	Soon	Operating
UK	EMEC	Scotland	Yes	Operating
	Wave Hub	Cornwall	Yes	Operating
	FaBTest	Falmouth	No	Operating
	PTEC	Isle of Wight	Yes	Under development
USA	U.S. Navy Wave Energy Test Site	Kaneohe Bay	Yes	Operational
	Pacific Marine Energy Center - North Energy Test Site	Newport, Oregon	No	Operational
	Pacific Marine Energy Center - Lake Washington	Seattle, Washington	No	Operational
	Pacific Marine Energy Center - Tanana River Hydrokinetic Test Site	Nenana, Alaska	No	Operational
	Southeast National Renewable Energy Center	Boca Raton, Florida	No	Planned
	Center for Ocean Renewable Energy	Iles of Shoals, New Hampshire	No	Operational
	Camp Rilea Test Site	Camp Rilea, Oregon	No	Operational
	Pacific Marine Energy Center – South Energy Test Site	Newport, Oregon	Yes	Planned
	California Wave Energy Test Center (CalWave)	Vandenburg Air Force Base, California	Yes	Planned

PROGRESS ON OPEN SEA TESTING

Several countries are working to advance research in open sea test sites by building the capability, infrastructure, and strategic partnerships to assist the private sector on the path to commercialization. The development of sea testing facilities for different stages of the development process is seen as a typically valuable measure at governmental level. Such infrastructure encourages ocean energy development by enabling practical experience of installation, operation, maintenance and decommissioning activities for full scale prototypes and farms, as well as on services and streamlining procedures.

Work is under way on several marine energy infrastructures. Several technologies are progressing into the open sea and others are very close to be deployed.

BELGIUM

A sea test facility was implemented at approximately 1 km from the Harbour of Ostend, not yet grid connected. Over the last year, a ¼ scale prototype called "Laminaria" has been tested at the sea testing site and a new deployment at EMEC is now planned for 2017.

CANADA

The Fundy Ocean Research Centre for Energy (FORCE) is Canada's research centre for tidal current energy, located in the Bay of Fundy. In addition to the 17.5 MW already approved in 2014 (4 berths), Nova Scotia announced an agreement with DP Energy to install a 4.5 MW tidal current project at a 5th berth. Feasibility and impact studies to expand the onshore electrical infrastructure to accommodate up to 20 MW started in 2015. Canada also established a Canadian Hydrokinetic Turbine Test Centre (CHTTC) in Manitoba, in the Winnipeg River, to test river current technologies; in 2015, 4 turbines were tested there. The 20 MW Annapolis Royal tidal barrage power plant commissioned in 1984 continues to operate today.

CHINA

In China, three test sites are being developed: a small scale test site in Weihai Shandong province, a tidal energy full scale test site in Zhoushan Zhejiang, initiated by China Three Gorges Corporation, and a wave energy full scale test site in Wanshan Guangdong. The upgrade of Jiangxia Tidal Power Plant from 3.9 MW to 4.1 MW was completed in August 2015. Guangzhou Institute of Energy Conversion (GIEC) with China Shipping Industry Co. has deployed their 100 kW Sharp Eagle Wanshan converter in November 2015. There are several research projects on wave and tidal energy progressing to sea trials. Further the concept of hybrid power stations (combining ocean, wind and solar energy) continues to be developed.

DENMARK

In Denmark, the Danish test site for Wave Energy Conversion (DanWEC) includes two sites, a benign site in Nissum Bredning and an exposed site at Hanstholm. Two wave rider buoys have been launched at DanWEC and a seabed survey has been carried out. Wave Piston was deployed at Hanstholm during the summer of 2015.

GERMANY

The NEMOS GmbH prototype has been tested at the Nissum Bredning test site in Denmark since August 2015, feeding energy into the grid. Another wave energy developer, SINN Power GmbH, announced, in late 2015, that their first wave power module was successfully installed on the Island of Crete, Greece. In addition to these projects, major German utilities are active in the ocean energy sector with test installations and prototypes around Europe.

KOREA

In Korea feasibility studies for test beds for wave and tidal energy have been carried out and it is expected that in 2016 the construction of a wave energy test bed of 5MW capacity with 5 berths will begin. In 2015 a new wave energy pilot plant - INWave - developed by INGINE Inc. was installed in Jeju costal water expected to be connected to local grid by mid-2016. The design of an active-controlled tidal energy converter developed by KIOST was completed in 2015 and will soon be tested at sea. Further much activity was going on at the 200 kW OTEC plant built in December 2014.

NORWAY

Runde Environmental Centre (REC), located on Runde Island on the Norwegian west coast, can accommodate wave energy devices for testing at several sites. One of the sites is now equipped with a sea cable to grid connection to shore.

The Norwegian developer Havkraft 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 over 4500 running hours and is now implementing the concept into offshore aquaculture and other applications. A

number of wave and tidal projects have made progress, preparing to be tested at sea in the next years.

PORTUGAL

In Portugal, Enondas, a subsidiary of the Portuguese Grid Transmission System Operator (REN), holds a 45-year lease for 320 km2 of seabed, since 2010, for the development of wave energy projects. However, there has been no progress regarding the development of infrastructures. Pico Plant, owned by WavEC, in Azores, continued operational in 2015 delivering electricity to the grid; after a successful series of tests, WaveRoller demonstration project in Peniche, is now developing a new unit, first of kind of the array.

SINGAPORE

There are recent initiatives led by ERI@N to develop test centres in Singapore for wave and tidal current projects. The Sentosa Tidal Test Site is one of these test sites to provide opportunities to develop local technologies to harness the energy available in the narrow channel between Singapore and Sentosa. The development of solutions suited for small islands, isolated villages, and emergency power supplies has been also promoted in Singapore.

SPAIN

Spain offers three test sites for wave energy testing: the Biscay Marine Energy Platform (bimep), an open sea test facility promoted by EVE (the Basque Energy Agency) and IDAE (Institute for Energy Diversification and Saving) in the Basque Country, which was officially inaugurated in July 2015. OCEANTEC, a Spanish company with two shareholders (Iberdrola and TECNALIA) was awarded a €2.5 million contract by EVE in November 2015 to test a wave energy prototype at Bimep. After the start-up of bimep, EVE is giving Mutriku's wave power plant a new use as test site, use that is compatible with the main activity of the plant that is to generate electricity from wave energy. This installation has achieved a cumulative production of over 1GWh after 4 years of continuous operation. The third one, PLOCAN on Canary Islands includes a marine area of 23 km2 from the coast to 600 m water depth. The submarine electrical infrastructure is still in the design stage expected to be ready in 2017. During 2015, two wave energy devices were installed and tested at Plocan site, Canary Islands: the W1 prototype developed by the Spanish company Wedge Global and PENGUIN II prototype developed by the Finish company WELLO installed in September 2015.

SWEDEN

In Sweden, Lysekil wave power research site was grid connected during 2015. Another test site in Sweden is the Söderfors marine currents research site. Both sites have devices in the water and are operated by Uppsala University.

During 2015, the Sotenäs project situated at the Swedish west coast progressed: 36 generators were in place and the subsea generator switchgear was deployed and connected to the Swedish national grid; the park is expected to start producing soon. Several other Swedish developers have made progress during the year and are preparing for demonstration in the ocean, primarily outside Sweden.

UNITED KINGDOM

UK has world-class facilities - EMEC, WaveHub, FaBTest, Narec and the testing tanks at University of Edinburgh and Plymouth University - to support the continuing development of the wave and tidal stream sectors.

Important achievements in UK are the beginning of the construction of the world's first multi-turbine tidal stream array project MeyGen Phase 1A; tidal stream developer Atlantis' acquisition of Marine Current Turbines and the successful deployment of Tidal Energy Ltd's DeltaStream device in Ramsey Sound, Wales. First pre-commercial wave array projects are progressing at the Wavehub: the 10 – 15MW CETO project developed by Carnegie Wave Energy Limited, the 10 MW Fortum project and the 10 MW Seabased wave energy technology.

THE UNITED STATES

Testing infrastructure and instrumentation is one major focus area for the Water Power Program. Several test sites for wave, tidal and river currents and OTEC are being developed with support from DOE. In 2015, the Azura wave energy prototype from Northwest Energy Innovations was installed at the Navy's WETS in Kaneohe Bay, Hawaii, and the Ocean Renewable Power Company (ORPC) deployed its RivGen® turbine in the Kvichak River, in Alaska. Further, a number of planned deployments in US have been announced by developers, including the Ocean Energy (OE) USA, Resolute Marine Energy, Fred Olsen and Columbia Power Technologies.

WORLDWIDE OCEAN POWER INSTALLED CAPACITY

NETHERLANDS

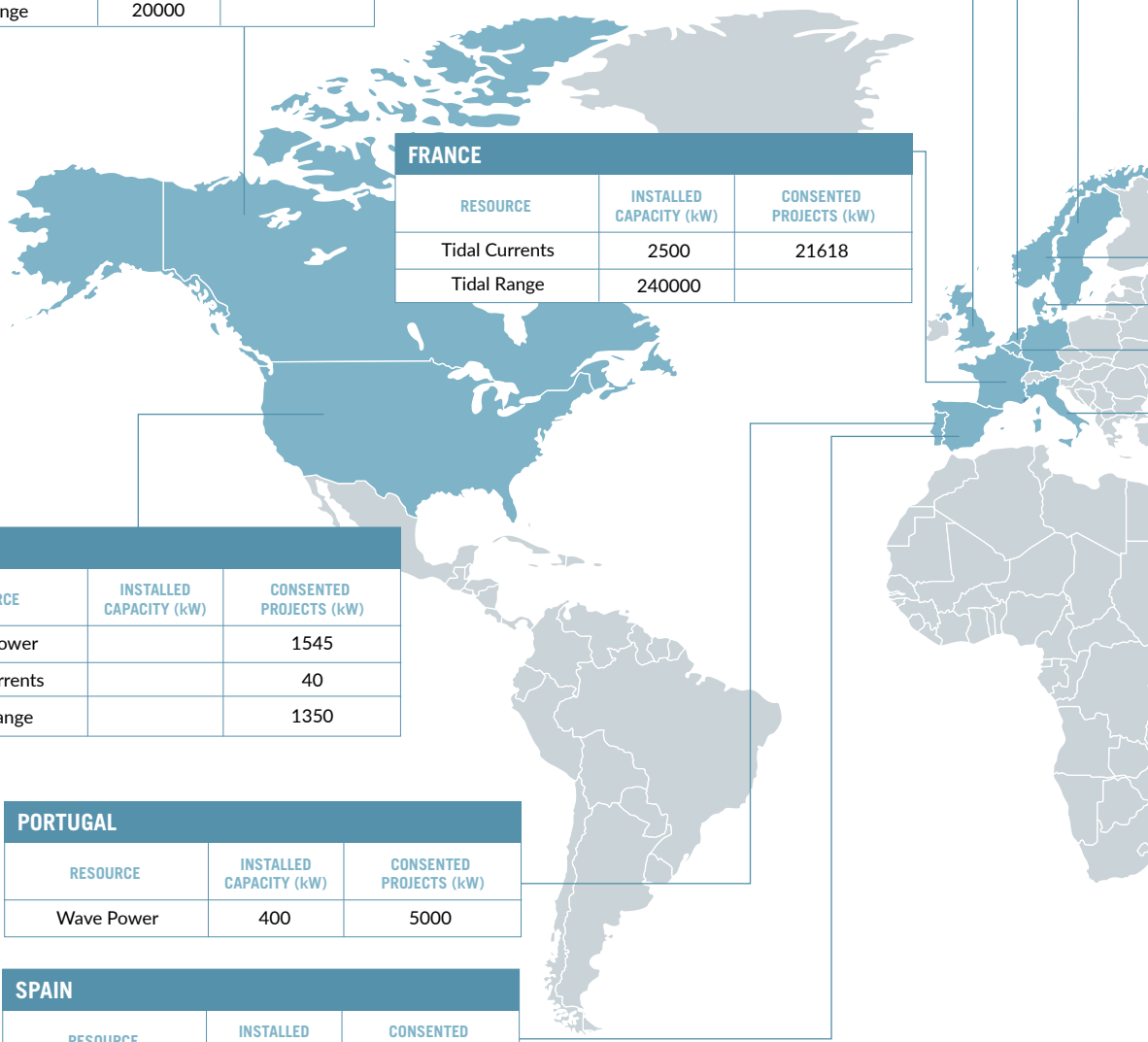
RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Tidal Currents	1300	1600-2200
Salinity Gradient	50	100000

UK

RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power	960	40000
Tidal Currents	2100	96000

CANADA

RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power	9	
Tidal Currents		20450
Tidal Range	20000	



FRANCE

RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Tidal Currents	2500	21618
Tidal Range	240000	

USA

RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power		1545
River Currents		40
Tidal Range		1350

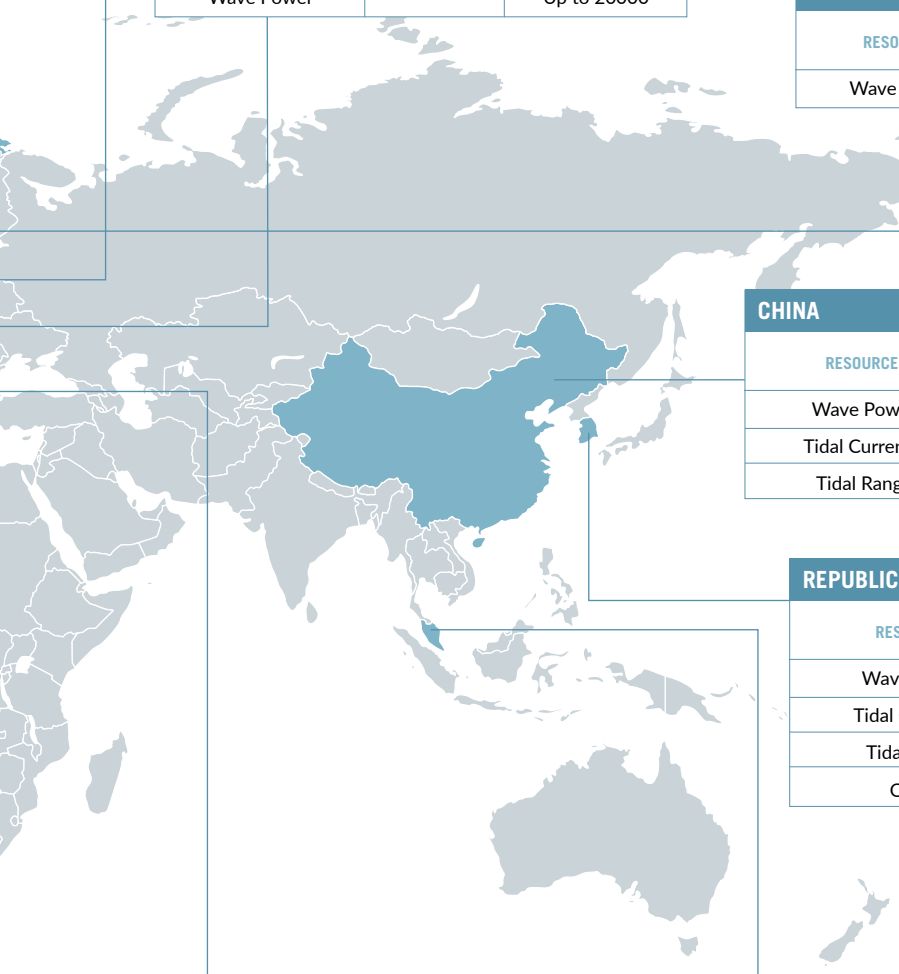
PORTUGAL

RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power	400	5000

SPAIN

RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power	296	

Technology is mainly on a demonstration phase of single units, some of the deployments are short-duration testing programmes and a few prototypes are initiating the first steps towards the commercialization phase. Therefore, this installed capacity is still not significant. Only tidal barrage systems achieved commercial scale and provide the principal contribution to the global ocean energy installed power.



SWEDEN

RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power	200	10400-10600
Tidal Currents	8	

DENMARK

RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power		50

BELGIUM

RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power		Up to 20000

NORWAY

RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power	200	

CHINA

RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power	450	2760
Tidal Currents	170	4800
Tidal Range	4100	200

REPUBLIC OF KOREA

RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power	500	500
Tidal Currents	1000	1000
Tidal Range	254000	254000
OTEC	220	220

ITALY

RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power		99

SINGAPORE

RESOURCE	INSTALLED CAPACITY (kW)	CONSENTED PROJECTS (kW)
Wave Power	16	
Tidal Currents		50
Tidal Range	5	

01 INTRODUCTION

VISION, ROLE AND VALUES

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 covers all forms of energy generation, in which seawater forms the motive power, through its physical and chemical properties.

Waves, derived from the transfer of the kinetic energy of the wind to the upper 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

"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 role within the context of this vision is to:

CONNECT | EDUCATE | INSPIRE | FACILITATE

ORGANISATIONAL VALUES

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 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 (INCLUDING A COMMITMENT TO EACH OTHER)

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

BRAND VALUES

TRUSTED INDEPENDENT SOURCE . where the information gained is trusted to be up-to-date, free of any commercial or other vested interests, relevant and practical such that reliance on it will enable forward momentum.

SUBSTANTIATED KNOWLEDGE . where the information gained is supported by respected and well researched and documented fact rather that the opinion of the author/supplier.

INSPIRING . a relationship with OES will provides inspiring and supportive leadership in the global development of ocean energy systems throughout the total supply chain.

CARING FOR SOCIETY AND THE ENVIRONMENT . from every perspective the development of ocean energy systems is done in a manner that enhances the global community, protects the environment and provides a base from which improvement to society will emerge.

COLLABORATIVE SHARING . we will all succeed as a result of collaboration and sharing in all areas of the ocean energy supply chain. OES will live out this value in all that is does.

THE OES VISION FOR INTERNATIONAL DEPLOYMENT OF OCEAN ENEGY

OES has a succinct brochure, which sets out the OES Executive Committee's views of the potential for development of ocean energy to 2050, including some specific and measurable goals for ocean energy, relating to job creation and emissions reductions.

Utilization of ocean energy resources will contribute to the world's future sustainable energy supply. Ocean energy will supply electricity, drinking water and other products at competitive prices, creating jobs and reducing dependence on fossil fuels. It will reduce the world energy sector's carbon emissions, whilst minimizing impacts on marine environments.

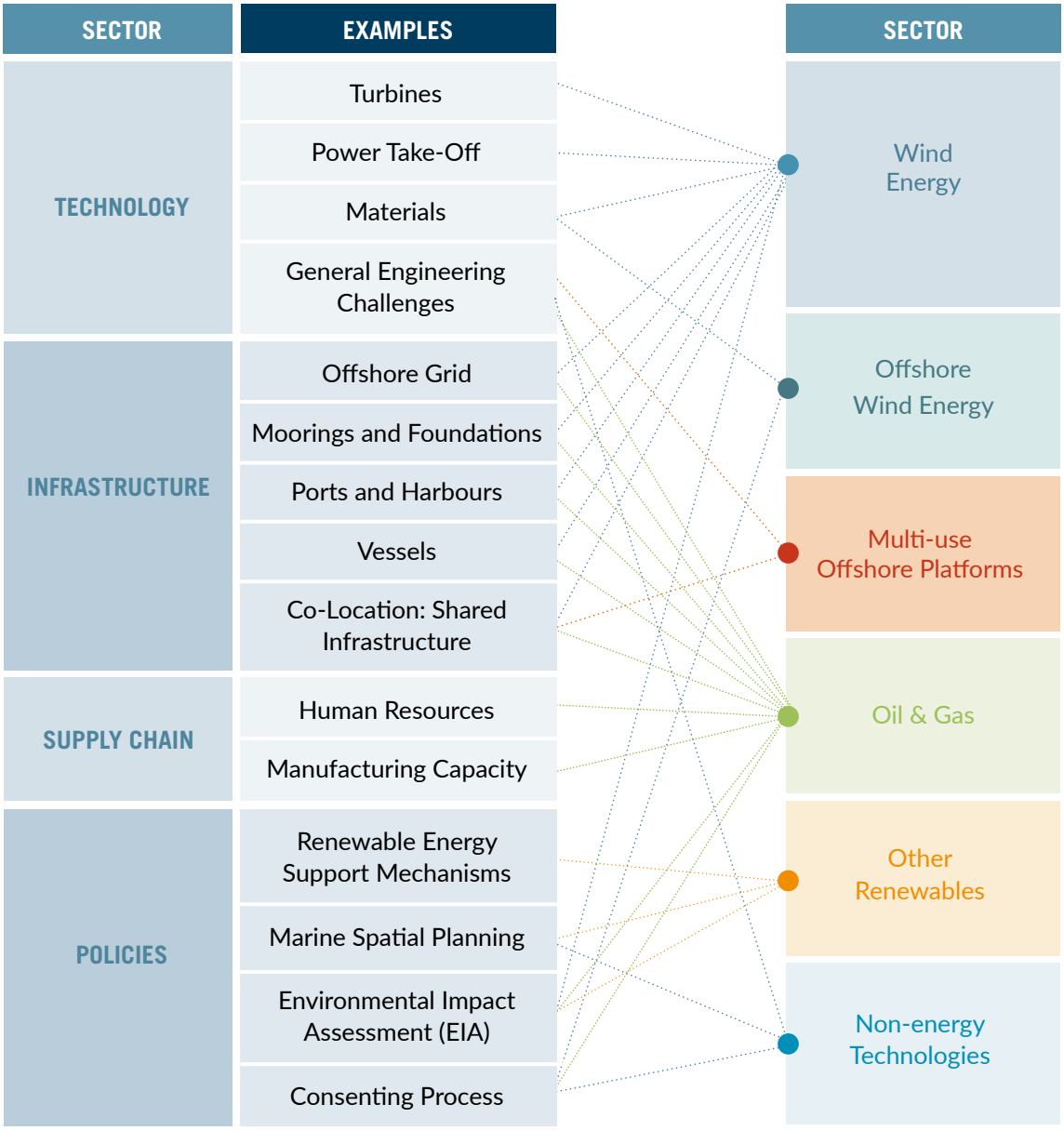
- Worldwide, there is the potential to develop 337 GW of ocean energy by 2050
- By 2050, the ocean energy deployment could create an estimated 300,000 direct jobs

BENEFITS OF OCEAN ENERGY

The resurgence of interest in marine energy arises from social and political changes requiring emissions reductions and replacement of fossil fuel generation with renewable energy generation. Governments around the world are setting renewable energy targets, both statutory and aspirational, whilst putting in place mechanisms and policies to secure greenhouse gas emissions. Some forms of ocean energy may be constant enough for baseload electricity generation, whilst most forms of ocean energy are reasonable forecastable and reliable, such that both diversity and security of supply can be enhanced. Some forms of ocean energy will yield alternative products, including drinking water, heating, cooling and biofuels. New industries may be created or transferred from declining industries, which will lead to creation of new jobs and/ or promote investment in new skills and capabilities.

SINERGIES WITH OTHER SECTORS

Future development of the ocean energy sector will be linked with developments in other sectors, such as offshore wind energy, exploiting positive synergies in technology developments (e.g., components), infrastructure, supply chain and policies. There will be significant opportunities for co-location of technologies; for example, ocean energy and offshore wind energy, utilizing common platforms or wave/ wave or wind/tidal hybrid systems. Mutual learning processes, shared infrastructure and innovations from a shared supply chain will be of great benefit to the future expansion of both the ocean energy sector and related sectors.



BENEFITS FROM INTERNATIONAL COLLABORATION

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

The Executive Committee (ExCo) is continuing to develop a suite of information dissemination tools that will assist the OES in becoming a leading international authority on ocean energy. Ocean energy remains an emerging technology area and will continue to benefit from the existence of the international collaboration mechanism offered under the Technology Collaboration Programme contract.

02

REPORT OF THE EXECUTIVE COMMITEE

MEMBERSHIP

The Technology Collaboration Programme on Ocean Energy Systems (OES) was initiated by three countries in 2001. As of December 2015, 23 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 and The Netherlands, ordered by sequence of joining the Agreement.

India and The European Commission have indicated to the Secretary that they will join OES in early 2016.

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

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

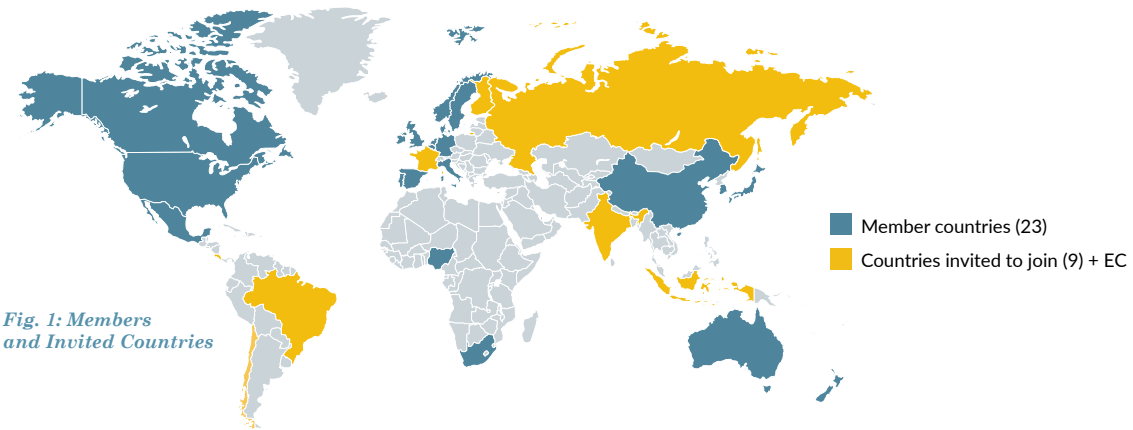


Fig. 1: Members and Invited Countries

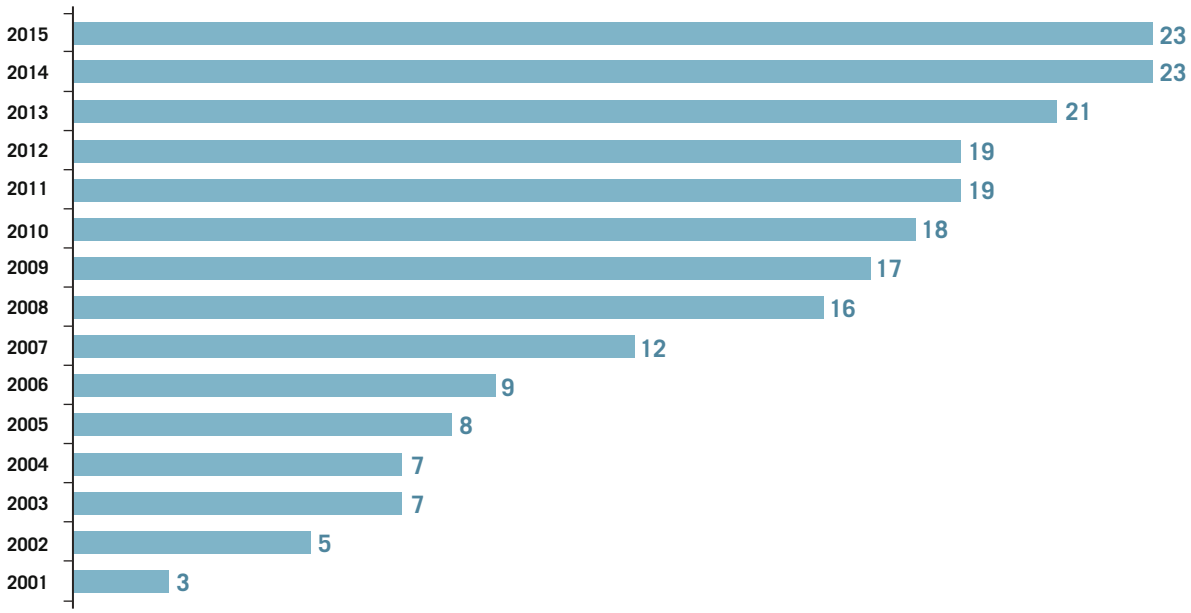


Fig. 2: OES Membership Growth

National governments appoint a Contracting Party to represent the country in the Executive Committee (ExCo) (Table 3). 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.

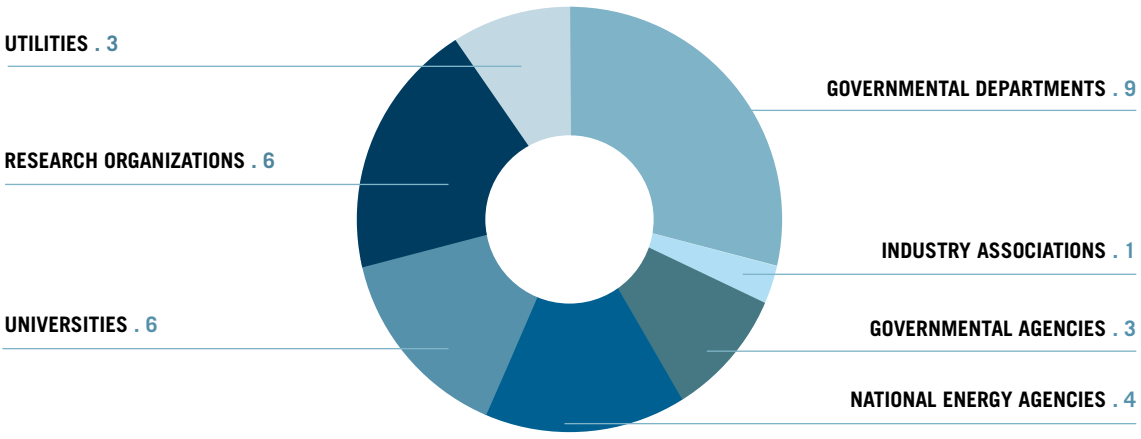


Fig. 3: Diversified representation of interests in the ExCo

TABLE 3: CONTRACTING PARTIES

YEAR OF SIGNATURE	COUNTRY	CONTRACTING PARTY
2001	Portugal	Laboratório Nacional de Energia e Geologia (LNEG)
	Denmark	Ministry of Transport and Energy, Danish Energy Authority
	United Kingdom	Department of Energy and Climate Change (DECC)
2002	Japan	Saga University
	Ireland	Sustainable Energy Authority of Ireland (SEAI)
2003	Canada	Natural Resources Canada
2005	United States of America	United States Department of Energy (DOE)
2006	Belgium	Federal Public Service Economy
2007	Germany	The Government of the Federal Republic of Germany
	Norway	The Research Council of Norway
	Mexico	The Government of Mexico
2008	Spain	TECNALIA
	Italy	Gestore dei Servizi Energetici (GSE)
	New Zealand	Aotearoa Wave and Tidal Energy Association (AWATEA)
	Sweden	Swedish Energy Agency
2009	Australia	CSIRO (Suspended in 2014)
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

Status in December 2015

EXECUTIVE COMMITTEE

The Executive Committee (ExCo) is the decision-making body of the OES and meets twice a year to discuss its Work Programme and share information among members. It comprises one voting delegate from each participating country.

Contracting Parties pay an annual membership fee to the Agreement Common Fund, which covers administrative expenses incurred in connection with the ExCo, including the secretariat functions, communication and dissemination activities, as well as sponsorship activities and short duration projects. The present membership subscription fee is € 7,000.

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 28th and 29th meetings of the ExCo were held during 2015. These were convened in Kassel, Germany (12 – 13 May 2015), and Cancun, Mexico (11 – 12 November 2015).

In Kassel, the delegates were are invited to attend a workshop on Ocean Energy, organised by Fraunhofer Iwes. The workshop was held on 11 May 2015 at Fraunhofer Headquarters, moderated by Mr. Jochen Bard, alternate member from Germany.

28th ExCo meeting in Kassel, Germany (12–13 May 2015)

29th ExCo meeting in Cancun, Mexico (11–12 November 2015)

MANAGEMENT & WORK PROGRAMME

The collaborative research work carried out by the OES is structured in specific tasks/projects using two distinct approaches:

- **Research Projects**, typically of 3 years duration (known as "Annexes" to the Implementing Agreement), conducted by a group of countries interested in the topic to which only participants in the Project contribute. Whenever three contracting parties support a proposal and sufficient funding is raised, a new research project can be established. Participation is usually by both cost-sharing and task-sharing.

- **Shorter projects or "Activities" of interest to all members** financed by the Common Fund. Usually the Terms of Reference of any proposed Activity are prepared by a volunteer member, a call is launched among the delegates and applications are evaluated and selected by a subcommittee of 3-4 voluntary ExCo members. The work can be conducted by a group of members and may include participation of external experts.

OES ACTIVE PROJECTS (2012 - 2016)

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

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TASK 5 . The Exchange and Assessment of Ocean Energy Device Project Information and Experience

Duration: 2012 – 2016
OA: National Renewable Energy Laboratory on behalf of the Department of Energy (DOE), U.S.
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 – 2016
OA: The University of Edinburgh (UK)
Partners: Nanyang Technological University (Singapore), Cardinal Engineering (USA), Power Projects Limited (New Zealand)
Participants: All member countries

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.**

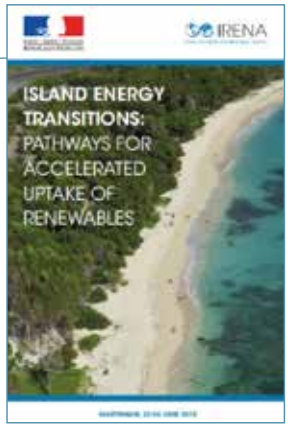
INTERACTION WITH THE IEA

OES interacts with the IEA through contributions to various IEA reports, the IEA OPEN Bulletin and trough participation in IEA meetings. In 2015 OES was present in the following IEA meetings:

- 67th Meeting of the Working Party on Renewable Energy Technologies (REWP)
  Paris, 25 – 26 March 2015
- IEA Meeting “Preparing the next 40 years of multilateral energy technology collaboration”
  Paris, 18 September 2015
- 68th Meeting of the Working Party on Renewable Energy Technologies (REWP)
  Lausanne, 21 – 22 October 2015

COLLABORATION WITH INTERNATIONAL ORGANISATIONS

COLLABORATION WITH IRENA



IRENA workshop “Island Energy Transitions: Pathways for Accelerated Uptake of Renewables”, Martinique, 22-24 June 2015
This workshop was organized aiming to provide an opportunity to discuss concrete options for renewable energy development on islands. Resource, technology, market, financing and other aspects of renewable energy development on islands were reviewed in depth. OES participated in this workshop exchanging views and experiences with many stakeholders. Based on this dialogue a set of recommendations were prepared for each energy sector, including marine energy development for islands.

COLLABORATION WITH THE OECD

The Future of the Ocean Economy
OES has been collaborating with the OECD project “The Future of the Ocean Economy: Exploring the prospects for emerging ocean industries to 2030”. The objective of the project is to conduct a global forward-looking assessment of the ocean economy to 2030, with special emphasis on the development potential of emerging ocean-based activities. For practical purposes, the project divides the ocean economy into **established marine activities and emerging ocean-based activities**. The project explores the growth prospects for the ocean economy and its potential for employment creation.
Following the joint OECD/OES WORKSHOP “Exploring the Prospects for Marine Renewable Energy to 2030” organised in May 2014 within the framework of the OECD Project, OES prepared a discussion paper submitted to the OECD.
More information about the OECD study:
http://www.oecd.org/futures/oceaneconomy.htm

COLLABORATION WITH INORE

The *International Network on Offshore Renewable Energy* (INORE) is an association of early stage researchers and professionals working in the fields of offshore wind, wave, tidal and ocean thermal energy conversion.
This network brings together many people with varied expertise and areas of interest, reflecting the need to communicate among the many disciplines involved in offshore energy.
The OES encourages this network and provides annual financial sponsorship for specific activities conducted by INORE, particularly to develop membership in new regions. One example of supporting international collaboration work is the "International Collaborative Incentive Scholarships" (ICIS scheme), whereby pairs or groups of researchers from at least two different countries are awarded a small bursary to fund (usually travel) expenses that will allow a piece of work to be carried out at one of the group member's organisations.

DISSEMINATION AND OUTREACH

Specific communication activities during 2015 have included:

WEBSITE

The OES dedicated website (www.ocean-energy-systems.org) is the primary source of communicating the activities of OES to a wider audience and has a restricted area to the ExCo delegates.

LINKEDIN GROUP

A LinkedIn group was set up in February 2015 and has now 170 members.

CLOSE LINK WITH ICOE

The ExCo has a close link with the International Conference on Ocean Energy (ICOE) and hosts past ICOE conference material at a dedicated website managed by the OES (www.icoe-conference.com), including the upload of all papers from previous conferences. In 2015, the OES collaborated with the organisation of the ICOE 2016, in particular the "poster award", a cash prize to 3 students selected by an international jury, composed of members of the ExCo.

ANNUAL REPORT

The Annual Report includes, each year, country reports provided by each member country on ocean energy policies, R&D and technology demonstration. This is intended as the flagship document for OES activities and a marker for industry development.

In 2015 a subdomain was created with an interactive online version: http://report2014.ocean-energy-systems.org/.

VIDEO ON OCEAN ENERGY

A video about ocean energy was prepared with the following goals: i) to promote ocean energy as a viable energy resource and educate decision makers as well as public about what ocean energy is and how it can contribute to a sustainable energy production, ii) to highlight recent developments, challenges faced by technologies deployed in the ocean and the need for adequate national policies to promote ocean energy, iii) to promote international collaboration. The video was placed at youtube and up to now had over 4000 visitors.

OES BULLETIN

A Bulletin issued each semester, immediately after each ExCo meeting presents most up to date information exchanged by the delegates. A free subscription is offered to all interested.

FACT SHEETS ABOUT EACH PROJECT

For each project a fact sheet is prepared summarizing the objectives and outcomes of each OES project:

PRESENCE IN MAIN EVENTS

Dissemination of OES activities has been an ongoing process, through the presence of OES representatives in well known conferences related to ocean energy. The table below lists the main events in 2015, in which the OES was represented:

EVENT	LOCAL	DATE
Ocean Energy Forum	Brussels, BELGIUM	16 April
Bilbao Marine Energy Week - Ocean Energy Conference	Bilbao, SPAIN	23 April
Conference “Island Energy Transitions: Pathways for Accelerated Uptake of Renewables”	Martinique, FRANCE	22 - 24 June
Ocean Energy Forum	Bilbao, SPAIN	1 July
Ocean Energy Europe – OEE2015	Paris, FRANCE	20 - 21 October

OCEAN ENERGY FORUM

The Ocean Energy Forum is a European initiative launched by the European Commission in April 2014 which brings together stakeholders to develop a shared understanding of the problems and to develop solutions. This Forum is a first stage of an action plan to accelerate the progress towards full industrialisation of ocean energy in Europe. The Forum will run for two years and its ultimate aim is to deliver a Strategic Roadmap for the development of the sector. It is divided into three workstreams: Technology, Finance and Environment & Consenting. Each of these workstreams has its own Steering Group, with representatives from all relevant stakeholder groups. The OES is part of the Steering Group on Environment & Consenting and in 2015 was represented in the two meetings of this group.

03 MAIN ACHIEVEMENTS IN 2015

TASK 4
ASSESSMENT OF ENVIRONMENTAL EFFECTS AND MONITORING EFFORTS

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

OPERATING AGENT
Jocelyn Brown-Saracino, US Department of Energy (DOE)

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, Ireland, Japan, New Zealand, Nigeria, Norway, Portugal, South Africa, Spain, Sweden, United Kingdom and United States of America

FURTHER INFORMATION
http://tethys.pnnl.gov

OBJECTIVES
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 second phase of Annex IV builds 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. The culmination of phase 2 of Annex IV will be a State

of the Science report that summarizes the state of knowledge of environmental effects of marine energy development, and seeks to place that knowledge in context of the progress of the industry worldwide. The official State of the science document is scheduled to be released in April 2016.

ACHIEVEMENTS AND PROGRESS IN 2015

During 2015, Phase 2 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;
- Progress towards the 2016 State of the Science report; and
- A partnership with a major international conference.

Progress towards each achievement is described in the following sections.

MEMBER NATION ANALYSTS

Phase 2 of 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 10 to 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;
- Advising and participating in the 2015 European Wave and Tidal Energy Conference in Nantes, France; and
- Acting as an ambassador for Annex IV in 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 phase 1, 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 2015, 3 research study forms have been added, while 2 project site forms and 4 research study forms have been updated. This results in 22 projects sites and 34 research studies being up to date according to the determined 18-month threshold. Additionally, 24 project sites and 17 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 80 project sites and 57 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 480 papers in the last year, for a total of 2069 entries. The collection includes information on offshore wind effects as well, but over half the papers are exclusively about marine energy development. Over the past year, *Tethys* has seen an 89% increase in pageviews, with an increase in total visits to the site of 23%. During 2015, fifteen reviewers (ten with a background in wave, tidal or current energy) 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 approximately 700 members of the Tethys community, providing 58 responses; these results gave an idea how users interact with the website. A report summarizing results of the peer review is available at: http://tethys.pnnl.gov/sites/default/files/attachments/PNNL-Tethys-Peer-Review-2015-final.pdf

ANNEX IV WORKSHOPS

Annex IV partnered with National Environmental Research Council to host a workshop at Ocean Business in Southampton, UK on April 16, 2015. This special session reviewed research and knowledge exchange programs for the development of novel technology, tools and methods, and considered the needs for the industry going forward. More information on this

special session can be found at: http://tethys.pnnl.gov/events/nerc-workshop-update-technology-and-tools-de-risk-and-streamline-development-special-session

Annex IV hosted a workshop on September 8, 2015 at the European Wave and Tidal Energy Conference with the objectives to 1) Brief the international marine renewable energy community on the Annex IV State of the Science Report; 2) Seek feedback from the community on topics of importance to the Annex IV initiative; 3) Provide methods for formal feedback on the Annex IV State of the Science Report. Brief presentations were given on selected chapters of the report, including: marine mammal collision risk, fish collision risk, electromagnetic fields, marine spatial planning, and case studies and consenting. Approximately 50-60 people attended this workshop. More information and archived presentations are available at: http://tethys.pnnl.gov/events/annex-iv-workshop-state-science

WEBINARS

Three webinars have been held by Annex IV in 2015, each bringing together between 55 and 100 people online to listen to recent research results and plans:

1. Effects of Energy Removal on Physical Systems, February 3, 2015

This webinar featured three modeling approaches that examine potential changes to physical systems. As wave and tidal devices are installed at commercial scales, measurements may be made to validate the models. Speakers for this webinar included: David Woolf, Heriot-Watt University; Zhaoqing Yang, Pacific Northwest National Laboratory; Kelley Ruehl and Craig Jones, Sandia National Laboratory.

2. The Effects of Electromagnetic Fields on Marine Animals, May 7, 2015

This webinar provided an overview of electromagnetic fields (EMF) in the marine environment, how additional EMF signatures from marine renewable energy devices may effect certain marine organisms, and how research efforts are addressing this issue. Speakers for this webinar included: Andrew Gill, Cranfield University; and Ann Bull, Bureau of Ocean Energy Management.

3. Marine Renewable Energy Test Centers and Environmental Effects Research, July 21, 2015

This webinar will discussed current environmental research efforts focused around marine renewable energy test centers and what is being planned for future test centers. Speakers included: Sarah Henkel, Northwest National Marine Renewable Energy Center; and Jennifer Norris, European Marine Renewable Energy Center.
The presentations and discussions from all webinars are archived at: http://tethys.pnnl.gov/mhk-environmental-webinars

STATE OF THE SCIENCE REPORT

The culmination of Phase 2 of Annex IV will be 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 impacts of marine renewable energy, 3) Collision risk for animals around tidal turbines 4) Risk to animal from MRE-generated sound, 5) Changes in physical systems, 6) Effects of electromagnetic fields, 7) Changes in habitat caused by MRE 8) Marine Spatial Planning, and 9) Case studies on permitting MRE devices. A complete draft will be released for public comment in February 2016 and it is anticipated that that final report will be released in April 2016.

PARTNERING WITH AN INTERNATIONAL CONFERENCE

Annex IV partnered with the European Wave and Tidal Energy Conference (EWTEC) during September 2015 in Nantes, France to enhance participation in the environmental track and increase the variety of papers presented. Twenty five papers were presented during this environmental track, an increase from 12 environmental presentations at the previous EWTEC. An average of 30 people attended each presentation and some presentations were so popular, not enough seating was available. The partnership with EWTEC was an opportunity for Annex IV member nations and researchers to share environmental research with a broad audience. More information about the presentations of the environmental track can be found at: http://tethys.pnnl.gov/events/11th-european-wave-and-tidal-energy-conference-ewtec

FUTURE ACTIVITIES

The major focus of Annex IV activities during 2016 will be finalizing the State of the Science report and publicizing its release in April 2016 through a combination of communication documents, presentations and webinars.

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.

As the second phase of Annex IV will draw to a close in 2016, a proposal for a third phase will be submitted to the OES Executive Committee. During phase three, it is anticipated that Annex IV would continue many of the same successful activities while exploring new ways to engage the scientific and consenting communities to help the MRE industry move forward.

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

PROJECT DURATION

2012 - 2015

PROJECT COORDINATOR

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

PARTICIPATING COUNTRIES

Further information www.ocean-energy-systems.org

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, Annex V 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. Two workshops have been held; the first was on the site development and operations for open water testing and the second was on computational modeling and analysis of marine energy converters, with two additional workshops being planned.

ACCOMPLISHMENTS

Since 2012, Task 5 has conducted three exchange workshops, in which participating members presented, collected, and reviewed project information, experience, and data. This Task has facilitated the presentation of projects from participating member countries in the areas of open ocean testing methods and test center operation as well as the verification and validation of computational modeling methods and reliability aspects of marine energy devices.

Workshop III: Designing For Reliability of Wave and Current Marine Energy Converters

Electricity Museum, Lisbon, Portugal, February 2015

An essential and necessary consideration for the design and cost-effective commercial operation of this technology is the reliability of the devices to operate for extended periods of time under harsh marine conditions. Reliability of the devices must be considered early in the design phase in order to significantly impact both the initial capital cost and the operation and maintenance costs for a long life. This workshop in February 2015

aimed to share information and knowledge on device analysis and design methods for assuring survivability, structural integrity, and fully operational power generation between scheduled maintenance events, as well as the needed support mechanisms to develop the envisioned high reliability technology.

The workshop was hosted by WavEC Offshore Renewables in Lisbon, Portugal. There were 22 participants from 7 countries that gave 13 presentations on research into the reliability of ocean energy converters. The final report is available at: https://www.ocean-energy-systems.org/oes-projects

FINAL WORKSHOP

Task 5 is planning to hold the final workshop on Ocean Energy Policies in May 2016.

WORKSHOP PRESENTATION TOPICS

WORKSHOP PRESENTER	PRESENTATION TOPIC
Daniel Laird, Sandia National labs - USA	Lessons Learned from the Sandia Wind Energy Reliability Database
Kyong-Hwan Kim, KRISO - Korea	A Design Method on Floating Wave-Offshore Wind Hybrid Power Generation System
Robert Thresher, NREL - USA	Some Reliability Lessons from Wind Energy
Marco Alves, WavEC - Portugal	Integrating reliability and uncertainty analysis in techno-economic models
Par Johannesson, SP Research Inst. - Sweden	Variation Mode and Effect Analysis for Ocean Energy Applications
Sam Weller, Exeter University - UK	Reliability Design Tools for Ocean Energy Arrays
Daniel Honfi, SP Research Inst. - Sweden	Case studies on reliability analyses with VMEA method
Vincenzo, Nava, TECNALIA - Spain	Standard-Compatible Robust Design Methods for Floating Marine Energy Converters (MECs)
Pauline Laporte, Weywada, DNV-GL	Validation of Loads and Structural Calculations for Ocean converters
Anders Goude, uppsala univ. - Sweden	Dynamics loads on a cross flow turbine during loss of utility conditions
Emiliano Pinori, SP Research Inst. - Sweden	Biofouling, corrosion, and material selection
David Snowberg, NREL - USA	MHK Technology Development Risk Management Framework
Claudio Bittencourt, DNV-GL	Plans for research on reliability of power take-off of tidal energy converter

TASK 6
WORLDWIDE WEB GIS DATABASE FOR OCEAN ENERGY

PROJECT DURATION
Started in June 2013; annually updated

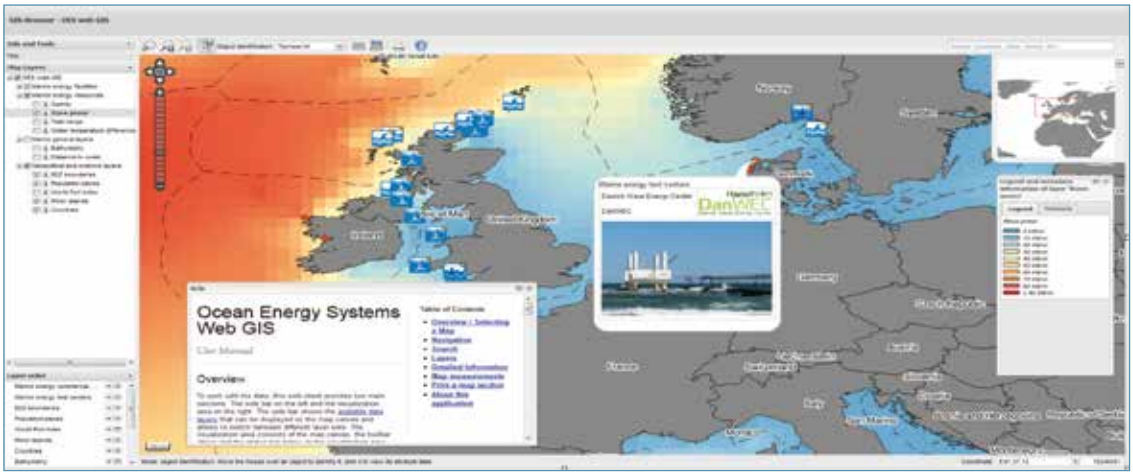
PROJECT COORDINATOR
Jochen Bard, Fraunhofer Institute IWES, Germany

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

OBJECTIVE
The goal of this project was to develop 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.

ACHIEVEMENTS
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 is able to display any combination of the provided information with the help of a pointand-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

PROJECT DURATION
October 2014 – March 2015

PROJECT COORDINATOR
Henry Jeffrey, The University of Edinburgh, UK

PROJECT PARTNERS
Alex Raventos, WavEC Offshore Renewables, Portugal
Julia Chozas, Consulting Engineer, Denmark
Mirko Previsic, Re Vision Consulting, USA

PROJECT ADVISORS
Kim Nielsen, RAMBOLL Group A/S, Denmark
David Aderibigbe, FOT-K Consortium, Nigeria

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

OBJECTIVE
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. In order 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.

The aim of this project was to provide an authoritative view on which cost reductions are feasible at a global level, taking into account the experience from other technologies. By undertaking a bottom-up assessment of the cost components of leading wave, tidal, and OTEC systems, this work investigated the development and fabrication of leading devices or systems, and their integration into commercial arrays and large scale power plants. The assessment included project development costs and operations and maintenance. The work was informed by a series of in-depth interviews with technology developers, and was build upon work carried out in European funded projects, such as SI Ocean, DTOcean, Equimar or Waveplam.

ACHIEVEMENTS
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.

Tidal stream energy converters have largely converged on horizontal axis designs; however there is a clear split in the development trajectory. The first considers large scale technology, greater than or equal to 500 kW in capacity, which has been the mainstay of development to date. The second considers the development of small scale technology less than 500 kW in scale. The data provided for this project suggests that the smaller scale technologies could offer a lower LCOE in the short term, with greater opportunity to achieve cost reduction targets through up-scaling of technology. Larger scale technology will reach cost competitiveness with the

smaller scale technologies only after considerable deployment has taken place.

The economies of scale and LCOE analysis clearly indicate that OTEC plants at a large scale are economically more attractive for the first project. In contrast, while wave and tidal stream energy technologies could achieve lower LCOE through multi-MW array deployment, the route to multi-MW arrays must first allow for development and deployment of the earlier lower-capacity arrays. LCOE reductions for wave and tidal stream energy are dependent on build out of early arrays, and not immediate progression on to large-scale multi-MW projects. Confidence in the technology must be gained at these early array stages prior to the progression and build-out of larger array capacities.

Wave and tidal stream energy technologies are modular in design, and therefore the range of perceived deployment capacities for future array projects varied widely.

There was a limitation of data which restricted the OTEC data set to values obtained through literature review. Consultation with existing OTEC developers suggested that the values from the literature review were appropriate for the imminent deployment of larger scale power plant currently under development, validating the approach used within this study.

Geographic distribution of the OTEC resource is limited to near-equatorial regions, due to the need to maximise the temperature differential between the warm surface water and the cooler deep-ocean water.

OTEC offers additional benefit of desalination in addition to electrical power production. This is particularly attractive given the suitable locations for OTEC technology deployment. This could impact the LCOE although it is an external factor. Wave and tidal stream energy offer the ability to be connected to a desalination plant, but would, in most cases, use the electrical energy produced by the ocean energy converter to provide the input power to a high pressure pump system for the reverse osmosis process (one exception is Carnegie Wave Energy's Perth Wave Energy Plant).

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

PROJECT DURATION
October 2014 – March 2015

OPERATING AGENT
Ana Brito Melo, WavEC Offshore Renewables, Portugal

PARTICIPATING COUNTRIES
All

PROJECT ADVISOR
Anne Marie O'Hagan, MaREI Centre at University College Cork, Ireland

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

OBJECTIVE
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.

In the EU, Maritime Spatial Planning and Strategic Environmental Assessment have been identified as tools which can support and inform future consenting of ocean energy projects. Other countries are in the process of developing MSP systems and some have already zoned sea areas for marine renewable energy development.

The operation of consenting systems will always be influenced to a large extent by national governance structures, given ultimate authority rests primarily with them. Likewise dedicated policies, strategies and incentives for renewable energy introduced by respective governments can have a significant impact on progressing industry development.

The proposed task aims to:

1. Analyse the operation of consenting processes in OES member countries through a collection of information on legal, policy and administrative issues.
2. Composition of a coherent overview, highlighting information gaps and areas which may require further attention and presentation of results.
3. To inform regulators and decision-makers on the key needs of the ocean energy sector from consenting processes.

ACHIEVEMENTS

The report **"Consenting Processes for Ocean Energy on OES Member Countries"** published in February 2015 summarises several aspects of the consenting process for ocean energy in the OES member countries, based on a collection of information provided by the Delegates.

It is clear from that report that the realisation of ocean energy projects in all the OES member countries continue 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. A governance framework that enables the development of the ocean energy sector is still required in most OES member countries. Consenting processes are one element of this framework. These must be considered within much wider management frameworks that are now beginning to include Marine Spatial Planning and risk-based approaches as well as continued environmental protection and increasing need to ensure public acceptance.

Whilst uncertainties with respect to environmental effects of ocean energy devices continue to be addressed through research programmes and collaborative efforts, there is a need to ensure that the knowledge generated from this work informs policy development and the future consenting processes to be applied to new and larger ocean energy developments.

An annual update of this report will be conducted in 2016, including a review of the following topics in each OES country:

- *Integrated planning:* to include information on the status of marine spatial planning in each member country, how site selection is conducted, how the needs of other marine sectors are taken into account etc.
- *Administrative procedures:* to include information about institutional systems specifically whether central coordination units or one-stop shops exist, if there are initiatives for simplified licensing systems and whether there are any on-going initiatives aimed at streamlining applicable processes;
- *Environmental Impact Assessment:* to include summary information on the environmental impacts that are most frequently encountered by developers and regulators, how projects are monitored post construction and how the resulting information is fed back into policy-making.
- *Public participation in decision-making:* to include an overview of how the public and other marine sectors are involved in decisions relating to ocean energy projects.
- *Other relevant information:* to include succinct information on any other national initiatives or programmes that are relevant to consenting and permitting in the OES country.

TASK 9
INTERNATIONAL OCEAN ENERGY TECHNOLOGY ROADMAP

PROJECT DURATION
October 2014 – March 2015

PROJECT COORDINATOR
Henry Jeffrey, The University of Edinburgh, UK

PROJECT PARTNERS
Roger Bagbey, Cardinal Engineering
John Huckerby, Power Projects
Srikanth Narasimalu, Energy Research Institute

FURTHER INFORMATION
www.ocean-energy-systems.org

OBJECTIVE
Roadmaps are an effective tool to underpin the identification of priority focus areas and investments to accelerate ocean energy technology development, allowing LCOE reductions to be realised. Additionally, roadmaps can facilitate the creation of international frameworks to accelerate the development and adoption of low carbon technologies. Unified international policies are a key step towards a successful marine energy industry and then the creation of an international roadmap is very important to achieve that goal.
The overall object of the ocean energy technology roadmap is to achieve LCOE targets within the ocean energy sector. This requires principal focus on two key areas: **Reliability Improvement and Performance Improvement.**

Specific objectives of the work include:
- Identification of the key gaps in knowledge in Ocean Energy technologies that are currently hindering cost reduction.
- To prioritise research and innovation activity requirements according to the previously mentioned challenges (both in the short term and the long term) for the efficient and effective progression of the ocean energy sector, overcoming the challenges and realising significant cost reductions.
- Engaging and mobilizing the supply chain for device and project developers to tap into experience and expertise from other industrial sectors, such as shipbuilding, fishing and aquaculture.
- Identify development timelines and milestones in order to measure and track progress, and ultimately the cost reductions, against OES expectations of the sector.

EXPECTED RESULTS
Additional benefits of this project will ensure:
- Influence in research and innovation funding strategies to address the relevant ocean energy priorities.
- The encouragement of closer collaboration and knowledge exchange between research organisations and technology developers and others outside of the existing ocean energy community.
- Underpinning research that enhances international collaboration, whilst influencing and guiding both political and business decision makers.
- The identification of correct policies and measures, implementation timescales, and specific topics on which to focus R&D and business investments to accelerate ocean energy technology development.

This project will lead to the production of:
- The underpinning information for an updated OES Vision Paper.
- Development of critical technology development strategy timelines.
- Identification and prioritisation of innovation synergies and commonalities between both countries and sectors.

04 INTERVIEW WITH FUNDING ENTITIES

INTERVIEW WITH:

ALISON LA BONTE
MARINE AND HYDROKINETIC TECHNOLOGY MANAGER
US Department of Energy

TIM HURST
MANAGING DIRECTOR
Wave Energy Scotland

MATTHIJS SOEDE
RESEARCH PROGRAMME OFFICER
DG Research & Innovation, European Commission

CHRISTOPH TAGWERKER
CLIMATE CHANGE DIVISION
Infraestructure and Environment Sector
Inter-American Development Bank

TAKAAKI MORITA
DIRECTOR
Marine Industry Development Office, Industry & Labor Department at Nagasaki Prefectural Government

SIMON ROBERTSON
PROJECT COORDINATOR
Nagasaki Marine Industry Cluster Promotion Association

Note: In July 2014, Nagasaki Prefecture was designated by the Japanese National Government as a "Marine Renewable Energy Demonstration Field" which is suitable for floating wind and tidal energy generation. Nagasaki Prefecture will promote the development of the Nagasaki demonstration field by attracting various demonstration projects from home and abroad in cooperation with the national government in accordance with a national government decision in 2012 to promote the development of a marine renewable energy demonstration field.

Ocean Energy technology is usually developed and brought forward by small companies. These had the entire development risk and needed to acquire external capital (partly Venture Capital) in order to proceed to full scale prototypes or first demonstration projects. The long time span between developing and commercialising not only a single technology, but an entire sector, obviously needs a serious and medium-long term commitment from the industry (utilities, industrial manufacturers…). Do you feel such commitment exists at this stage? If not, how could such commitment be triggered in your opinion?

ALISON LA BONTE:

At this stage of technology maturity, a serious commitment does not yet exist from utilities, original equipment manufacturers, and other supply chain entities that are critical to the realization and larger-scale deployment of viable technologies, such as: port infrastructure, a dedicated supply chain, and access to installation, operation, and maintenance vessels. To attract this kind of commitment, the sector has to demonstrate that the business opportunity is real and achievable.
The U.S. Department of Energy (DOE) focuses on addressing the following key challenges to make these opportunities real and achievable:

a. Accelerate technology convergence by focusing development on the most promising technology pathways. The marine and hydrokinetic (MHK) energy sector is currently made up of a diverse set of technology designs. At this time, limited data is available to identify the most promising configurations that have the potential to offer high-performance results at low-cost with high reliability.

b. Demonstration testing of existing devices that are ready to test at full-scale to validate operational performance in a realistic resource environment, while simultaneously monitoring environmental interactions. In addition, this testing will provide data and information on installation procedures, operation and maintenance logistics and procedures, and device reliability.

c. Assessing potential environmental impacts through scientifically designed field research, developing new—more cost-effective—environmental monitoring technologies and instruments, and then validating them during device demonstration testing. The lack of baseline environmental data at high-potential ocean energy deployment sites can drive environmental and regulatory approval expenses to 30%-50% of total early-stage MHK project development costs.

TIM HURST:

The commitment does't exist at this time. The experience of Pelamis and Aquamarine in the UK and a shift away from marine renewables by the UK government has caused potential investors to step back from the industry. Before, these investors and OEMs will return there needs to sufficient technical success demonstrated to show beyond doubt that the large investment required to commercialise the technology can be justified. The objectives of WES are to fund core wave technology to the proof of concept stage and to demonstrate that wave technology is viable.

MATTHIJS SOEDE:

Indeed a medium-long term commitment is needed for the technology development. However, we should not forget that researchers and technology developers are already many years active in this field and there have been major investments already and everybody is expecting concrete results right now.
For sure there is commitment. From the policy site I see huge interest for Ocean Energy by the support for the Ocean Energy Forum, and different financing instruments on a national and international level. But also commitment from an industrial perspective. For instance, if you analyse the members of the Ocean Energy Europe Association you can see clearly that manufacturers and utilities are interested in ocean energy technology development. Another example is that they are participating in our demonstration projects in Horizon2020. At the moment we have never financed so many ocean energy projects on a European level like now. I hope we will have great results in the coming year helping the whole sector to develop.

TAKAAKI MORITA AND SIMON ROBERTSON:
There is no widespread industry commitment to ocean renewables in Japan at this time.
However, various stakeholders in the Nagasaki Prefecture located on the island of Kyushu in Western Japan have been making a gradual commitment to the development of offshore renewables. This commitment has been tangibly demonstrated by the installation of the first grid connected 2MW floating offshore wind turbine in Japan which was installed in 2013. At present a consortium formed from Nagasaki's local industry, the Prefectural Government and other stakeholders are developing plans to establish a tidal energy and floating offshore wind demonstration centre within the Prefecture. Investment in the Nagasaki demonstration centre will serve as a key platform upon which Nagasaki, Japan and Asia can facilitate the commercialisation of offshore renewables.
The demonstration centre will enable these novel technologies to demonstrate that they are effective solutions which can offer a competitive cost of energy to induce a serious long-term commitment from major industrial players and other investors.
 In order to help trigger a long term commitment from the industry, it is necessary for the centre to successfully demonstrate renewable energy turbines, even at a modest level.
In addition to proving the technology, a positive regulatory environment including public funding support is required to commercialise the sector. Moreover, addressing the wide range of issues involved requires close cooperation between Government, industry, investors and device developers. Whilst much is being achieved by the strong long-term commitment at a regional level in Nagasaki, more widely in Japan higher levels of commitment from large industrials, utility companies and the Japanese Government is essential.

CHRISTOPH TAGWERKER:
In Latin America this commitment does not exist. Latin America is still a technology importer and as such is more focused on implementing already proven technologies rather than supporting technology development, especially in the case of renewable energies. Much stronger public sector support and policies would be necessary to trigger that support.

Tidal current energy has reached a point of starting pre-commercial development, because in several projects reasonable responses to the technical challenges could already be found. At present stage, would you see tidal current energy projects and wave energy projects, among other less-established ocean energy concepts (salinity gradient, OTEC) with the same type of support? Or would you agree that wave energy (and others) might need a different funding approach?

ALISON LA BONTE:
In the United States, funding for each of the ocean energy technologies has been primarily dependent on the relative abundance of the resource (wave, current–tidal, river, ocean, OTEC, and salinity gradient) at the national level. While the maturity of each of these technologies is indeed different and influences the funding approach, DOE maintains that the wave and current energy technologies still need fundamental research, development, and demonstration (RD&D) funding before larger-scale deployment funding can be effectively employed to incentivize commercial projects. The funding approach for RD&D is motivated by DOE Energy Efficiency and Renewable Energy's five core principles: potential for impact; additionality (i.e. DOE investment will make a difference beyond what would otherwise occur through the private sector); openness to new ideas, approaches, and performers; results in enduring U.S. economic benefit; and a proper fit with the role of government.
I would like to give two recent examples of diverse funding approaches showing how the unique role of the federal government can be leveraged:

The System Performance Advancement funding opportunity, and the Wave Energy Prize. These two funding approaches were designed by DOE, drawing on the previously mentioned core principles, emphasizing the unique role that government can play in advancing technologies and establishing their techno-economic competitiveness.

i) System Performance Advancement: This solicitation was designed to spur innovation for next-generation water power component technologies and attracting technology developers from related sectors to apply their expertise towards advancing componentry for marine energy applications. The selected projects will address technical challenges in three areas: a) advanced controls, b) power take-off, and c) innovative structures. Through this research funding, the projects will improve the performance and reduce the cost of MHK technologies. Research and development supported by this funding will advance the market-readiness of MHK systems through the continued development and use of innovative components for wave and tidal energy devices.

ii) Wave Energy Prize: DOE's Water Power Program designed an aggressive and ground-breaking technology demonstration prize to spur innovation and establish pathways to sweeping cost reductions and commercial scale technology development. The prize approach was employed, because the wave energy industry is an emerging technology that has vast potential for innovation. The Prize provides a needed framework, complete with clear metrics and goals, necessary to develop game-changing solutions. Specifically, the Wave Energy Prize has set a threshold goal to double state of the art performance, and is facilitating rapid advancements by offering incentives to attract new and existing players to the problem. The incentives are a monetary prize purse of $2.25M, and an opportunity for tank testing and evaluation of 1/20th scale WEC prototypes at the nation's most advanced wave-making facility, the U.S. Navy's Maneuvering and Seakeeping (MASK) Basin in Carderock, MD. The Prize also offers important non-monetary benefits that will result in additional value to the industry, such as publicity and investor engagement, along with the ability to compare performance across diverse device configurations.

TIM HURST:

Agreed, funding for wave should still be focussed on innovation support. One key difference between wave and tidal is that a number of key OEMs are engaged in Tidal.

CHRISTOPH TAGWERKER:

I agree that wave energy needs a different funding approach with different goals. Perhaps incentives should be designed with a focus on driving driving convergence of technology solutions. Could incentives for collaboration between developers of similar technologies help here in order to somehow share lessons or information? This could somehow help reduce support needed due to synergies. More public information is needed and non-disclosure of information in the industry is a barrier for further development.

TAKAAKI MORITA AND SIMON ROBERTSON:

Japan is still at the stage where it has to demonstrate a successful tidal energy turbine project to investors, the business community and other stakeholders. The proposed demonstration centre in Nagasaki Prefecture for tidal energy and floating offshore wind projects will facilitate this. Nagasaki welcomes collaboration with developers from around the world to accelerate these developments. In addition, Nagasaki hopes that the development of other novel renewable energy technologies such as OTEC and salinity gradient generation will provide a positive effect to the development of tidal and floating offshore energy technologies.

It is essential that funding support is designed on a case by case basis to meet the needs of developers and the market situation at the time. Tidal energy, wave energy, OTEC and salinity gradient generation technologies and markets all face different development challenges. Funding support should be provided by taking into account the different circumstances surrounding the needs of individual developers and varying market environments that are prevalent at different times.

Wave energy has suffered some credibility loss, since several ambitious projects failed to meet the investors' short term expectations in the last decade. Nevertheless, the RTD support on an international level has increased. How important would you think is transparency and open sharing/discussion of results in this phase of the sector? Could a public-financed initiative link more substantial support to the obligation to give access to results to a broader scientific and technical community, and/or joint development projects that do not exclusively aim at one technology?

ALISON LA BONTE:

Transparency and open data is extremely important to accelerate technology development in order to avoid funding the same technology evolution by several different companies, and also to attract new players from related offshore and engineering sectors. Awardees who received U.S. public funding through financial assistance mechanisms are able to hold their data proprietary for a period of up to five years, after which it is to be made available to the public. To make this data easily searchable and of value, DOE has established the MHK Data Repository, which is a data sharing platform to help store and disseminate open-source data relevant to the design and development of marine energy technologies. DOE now also requires that a subset of the data collected during the award period of performance be made immediately available to the public through the MHK Data Repository. Additionally, the degree to which applicants are willing to publically share valuable data is used as an evaluated criterion in both the merit review and award selection process.

DOE's Water Power Program is also excited about a new initiative that is focused on creating a "Structured Innovation" framework to help develop optimal WEC technologies. This initiative has recently been kicked off through a joint effort by the National Renewable Energy Laboratory and Sandia National Laboratories. This project is not aimed exclusively at one technology, as the national labs and other partners in this joint development effort will have no attachment to a single "idea" or "innovation." By engaging with industry, the team will approach the engineering problem of defining what would be an optimal wave energy conversion based on fundamental design principles. First, they will specify the basic functional requirements of the system and then set minimum metrics that will serve as the required performance standard for each of these functions. Then they will employ a technique for innovative problem solving, which is based on a theory that defines generalizable patterns in the nature of inventive solutions, along with the distinguishing characteristics of the challenges that these inventions have to overcome.

TIM HURST:

It is very difficult to achieve sharing of results, particularly negative results, when small technology companies want to project their image and stock value. At Wave Energy Scotland (WES) we fully fund technology development and put a contractual requirement on participants to share and disseminate results within our technology programme. Expanding this programme approach to other EU member states would be a significant step forward.

TAKAAKI MORITA AND SIMON ROBERTSON:

Globally there have been many successes but also failures across all offshore renewable energy technologies not just wave energy. Given the finite resources available within the sector it would be a shortcoming to not make efforts to share key lessons and knowledge as widely as possible. Knowledge sharing would help the global community of developers and funders to accelerate progress and find the best solutions to reduce the cost of energy. Of course such knowledge sharing needs to be balanced with the commercial interests of device developers and in particular intellectual property requirements.

There are many opportunities for joint development projects within offshore renewables such as deployment methods for a turbine system as well as operations and maintenance activities. This requires the cooperation of multiple developers to agree to joint developments of such technologies. Public entities and funding organizations are well placed to facilitate the drawing up of the necessary

framework arrangements for undertaking such collaborations.
In Japan an appreciation of the advantages of knowledge sharing and collaboration is widely held by funders and industry. The Ministry of the Environment, acting as a key funder, has been supporting the 2MW Floating Offshore Wind demonstration project which is a joint project among industrial and academic partners in the waters off Nagasaki Prefecture and in 2013 this became the first grid connected floating offshore wind turbine in Japan. To help inform future projects, knowledge sharing reports and data relating to technical and environmental aspects of the project will be produced and disseminated.

MATTHIJS SOEDE:
I think sharing information is extremely important for the sector. It is maybe not that you share exactly all the details of your technology, but everybody is facing the same challenges working in a harsh environment. Everybody did make mistakes or had bad experiences, but these are giving very useful information for new innovations. For that reason we asked Ecorys together with Fraunhofer to conduct a study in 2016 on lessons learned for the whole sector. Ocean energy-technology companies should embrace and share knowledge about challenges and failures and view them as learning opportunities. The study is meant to open up the sector and to prioritize future activities, and I would like to ask everybody to cooperate and to share their knowledge.

CHRISTOPH TAGWERKER:
Yes, I agree that a public financed initiative would be more effective as it would allow easier access to information. In the early technology development stage transparency and information is crucial to design and size funding support.

In order to seriously advance the ocean energy development, only extensive field testing and gradual improvements will help to overcome the technical challenges in the present development phase. Projects have to be monitored heavily, and quick interaction in case of unexpected problems must be assured. Typically, this means too heavy commitment of one single development team at a site. EMEC has been a very important fore-runner in concentrating know-how in one test centre, but other regions require similar infra-structure, in order to enable the sector to develop. Could it be an option to create an international network of 3-5 of such centres in various sea conditions, mostly run by public funds? In addition, could device developers be offered grant schemes to access these sites, where they are obliged to undergo pre-defined test schemes including sharing/publication of results?

ALISON LA BONTE:
DOE's Water Power Program agrees that a diversity of test sites is required in order to span the range of energy intensity that developers are ready to test at as their WEC technology steps through the Technology Readiness Level progression. Where these test sites are located is important as:

a. The location of the site will benefit from the development of a supply chain and established capability in the local workforce, thus readying the broader region around the test site towards ultimate commercial projects.

b. Testing in proximity to the ultimate commercial site can help build knowledge and mitigate

environmental and social impacts of project development.
For these reasons, the United States is investing in the development of a fully energetic wave energy device testing facility that will play an integral role in advancing wave energy technologies from early-stage prototypes through commercial ready products. In addition, this facility will provide a training ground for the next-generation of wave energy researchers.

TIM HURST:
There is no shortage of test sites for wave devices – the EMEC wave site has never been full! The idea of using a pre-defined/standard test methodology is good and would increase credibility and allow better comparison between technologies.

CHRISTOPH TAGWERKER:
Yes, local test centres are important; however there should also be local funding support to create a feed/pipeline of projects to be tested at the sites. In other words make sure to have enough demand for the different sites.

MATTHIJS SOEDE:
We have in Europe already several test sites and in other parts of the world there are more. Think about PLOCAN, BIMEP and Wavehub, AMETS, Galway, FORCE Canady, Hawai USA. They all have their own characteristics. I don't know in which way these sites are really sharing their knowledge. Or should I say 'can share' their knowledge.
Most of these test sites have been set up by public finance and they are still financed by grant schemes. The demonstration projects which we are supporting are mainly using these test sites, because of the existing infrastructure the overall cost for these projects will be lower and they have in general already the necessary permits to do experiments. I think the IEA OES can play a role in a better coordination and cooperation. It would help the sector and if the sector is successful it will be beneficiary for all test sites.

TAKAAKI MORITA AND SIMON ROBERTSON:
Yes, the parties seeking to promote marine renewable energy projects in Nagasaki Prefecture support the development of a global network of test facilities to allow developers to undertake R&D and prove the effectiveness of offshore renewable energy technologies. In July 2014, Nagasaki Prefecture was designated by the Japanese National Government as a "Marine Renewable Energy Demonstration Field" which is suitable for floating wind and tidal energy generation. Nagasaki Prefecture will promote the development of the Nagasaki demonstration field by attracting various demonstration projects from home and abroad in cooperation with the national government, satisfying their 2012 decision to promote the development of a marine renewable energy demonstration field. Following these decisions Nagasaki has been actively developing the plans for a fully-fledged world-class tidal energy and floating offshore wind energy facility in an effort to operate on a full scale in the near future.
The Nagasaki Prefecture demonstration centre in Western Japan is ideally located to enable collaboration and knowledge sharing across neighbouring Asian and South East Asian countries and to act as an Asian hub for development, in much the same way EMEC is in Europe. Planners of the centre are ready to make it an active participant in a strong network of international test centres and to this end are already collaborating actively with top officials at EMEC, initially for the development of the test centre. In due course, the planners are also likely to do so regarding the R&D which takes place there.
It is expected that most projects at test centres will require grant funding and other support to access the sites. Such funding presents an excellent opportunity to require valuable knowledge sharing and publication measures whilst respecting commercially sensitive information.

All ocean energy technologies are expected to go through a phase of development. Can you comment on the possibility and implementation of a stage-gate approach, in other words, only engaging funding for the next phase if the performance indicators of the former phase are achieved?

ALISON LA BONTE:

DOE's Water Power Program agrees with the need for a stage gate approach. The Water Power Program currently requires awardees to have metrics and measures for each stage of development. Applicants are required to quantitatively state the improvement that will be achieved at each stage with the awarded funds.

The most aggressive implementation of stage gates and performance metrics in the Water Power Program is through stage-gate down-selection in the Wave Energy Prize. In the Prize, competing technologies must measure up against stage-gate metrics transparently stated in the Prize Rules, and to be eligible to be awarded prize money in the Wave Energy Prize, teams must have met a minimum threshold performance metric.

The Prize measures the state-of-the-art performance of WECs through a new metric created in the prize design process, the ACE metric—Average Climate Capture Width per Characteristic Capital Expenditure. ACE represents the energy captured per unit structural cost of WECs. This is a proxy metric for LCOE. LCOE is a metric that allows for comparisons of the costs of electricity produced by different means and sources (like solar, wind, fossil, and so on). The state-of-the-art value for ACE is 1.5 meters per million dollars (1.5 m/$M). A Finalist becomes eligible to win the $1.5 million grand prize if they double ACE to 3 m/$M during the final round of testing.

To achieve the Prize goals stated above, the participants are required to undertake more and more challenging WEC design and build tasks across each stage of the Prize—the results of which are evaluated by a Judging Panel. First, Registered Teams were required to submit a detailed Technical Submission describing their proposed innovative WEC technology. Qualified Teams are selected by the Judging Panel based on a rigorous evaluation of these technical submissions. Teams are then required to numerically model and build a small scale (1/50th) model of their device—a model that would be tested, and subsequently evaluated, and compared not only against other devices, but against performance metrics developed by the Prize, as well. Successful Qualified Teams will be deemed as Finalists after the second round of judging. Teams who pass through this stage will be given seed funding, and then be required to build larger (1/20th) scale models of their devices with control capabilities. These 1/20th scale models will be tested in the Naval Surface Warfare Center's MASK Basin in Carderock, MD. The Judging Panel will evaluate whether teams double ACE during this final round of testing, thus determining which teams are eligible to win a prize, and which of these teams ranks the highest in Hydrodynamic Performance Quality to determine the winner of the $1.5 million grand prize.

The benefit of this kind of quantitative and transparent approach is that the Prize will not only achieve the sector rapid innovation needed to reach a new state of the art performance of the technology, but also will raise the confidence of investors in the technologies that have succeeded through the stage-gate process.

TIM HURST:

The stage gate approach is exactly what WES has now implemented with its two innovation calls. Developers are funded for a discrete phase of development and can only move to the next phase if they meet the requirements of the stage gate technical milestone. This provides continuity of funding for those who meet their milestones and an element of competition between technologies.

TAKAAKI MORITA AND SIMON ROBERTSON:

A stage-gate approach would deliver a robust technology development approach which in the long run should help reduce costs and risks. Most technology developers and funders acknowledge the importance of a stage-gate technology development but this can often be compromised by commercial and financial constraints.

Public entities and funding organizations therefore have a responsibility to set appropriate technological goals for developers as part of a stage-gate development approach. It is vital to carefully devise a system which is flexible enough to allow developers to progress rapidly when ready to do so but one which also permits further development iterations if required before the next stage and up-scaling.

A stage-gate approach to development has been adopted here in Nagasaki Prefecture with the 2MW floating offshore wind turbine having been preceded by a smaller 100kW part scale demonstrator. Having been successfully demonstrated and yielded much knowledge and learning, the next technology step is expected to involve a multiple-turbine farm based on the successfully demonstrated 2 MW turbine.

MATTHIJS SOEDE:

I agree that the technologies go through a phase of development. Recent project developments in tidal energy are really encouraging and I hope we will see great results in the coming year.

We introduced in Horizon 2020 the Technology Readiness Levels and in fact we have different programmes for technologies in a different stage. We have calls for future emerging technologies for technologies on a lower technology readiness level, but also calls for large demonstration project, where you need to proof that the technology is already on a higher TRL. We introduced in 2015 a new financing instrument InnovFin Energy Demo Projects to bring technologies further to the market. Unfortunately I see some developers trying to apply in all different possible programmes and just adopting their 'technology readiness level' according to the requirements of the respective funding scheme. I think this is not fair to the funding organisations and make makes them suspicious. It is also not fair to themselves; they are putting themselves in a situation which they shouldn't be and that enlarges the risk on failure. It is also putting stress on the whole sector because 'again' an ocean energy project is failing.

CHRISTOPH TAGWERKER:

It might be difficult to apply during technology development and definition of success is important here. If something hasn't worked as expected in one stage that doesn't mean it won't work in the next phase because there could be lessons for improvement which make the next stage work. In other words most lessons are learned by failure not by success.

INTERNATIONAL SITUATION ON
OCEAN ENERGY IN PARTICIPATING COUNTRIES

05

COUNTRY REPORTS

Listed by alphabetic order

BELGIUM

JULIEN DE ROUCK AND TIM VERBRUGGHE *University of Ghent*

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 ± 2400 MW of offshore wind power by 2020.

MAIN SUPPORT INITIATIVES

A green energy certificate market is implemented to support renewable energy production with Tradable Green Certificates (TGC). For each renewable technology, a stakeholder analysis is put forward to determine the level of support. A generic business case is constructed with input of the developer, the technology supplier, investors, banks. 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.

NATIONAL SEA TEST FACILITIES

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.

LICENSING AND ENVIRONMENTAL IMPACT ASSESSMENT

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 266 MW wind and 5 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.

RELEVANT DOCUMENTS RELEASED

The BOREAS final report that describes the assessment of the wave and tidal energy potential in the Belgian North Sea is available online (www.belspo.be).

RESEARCH & DEVELOPMENT

KEY R&D INSTITUTIONS AND RELEVANT R&D PROJECTS

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. The project has been partly funded by IWT (Flemish Agency for Innovation by Science and Technology). The FlanSea prototype device of 4.4m diameter, 5m height and 25 tonnes weight was commissioned outside the Harbour of Ostend in July 2013. It has to be considered as a scale model at scale ½. 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 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. 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 sits in the water with its top near the surface. When wave power exceeds the level necessary to produce nominal power the device submerges. The device finds the ideal height in the water column where there is still enough motion in the water to produce nominal power but without undergoing the excessive motion near the water surface. This results in a very effective way of regulating energy input into the device. As a result of the storm protection strategy the device can be optimized to produce optimal in smaller more common waves. This not only results in a

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

lighter, cheaper and more effective device, it also results in a very high capacity factor.
Over the last year a fully functional ¼ 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 1kW at 0.5m waves. Even though it survived stormy conditions with waves up to 2.7m that have an energy content of 46 times the waves needed to produce nominal power. Due to the storm protection strategy strains and forces on the device and moorings were limited to the level comparable with 0.5m 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.

TECHNOLOGY DEMONSTRATION

MAJOR INDUSTRY PLAYERS

The Gen4Wave platform was founded in 2012 and is a blue energy stakeholders' organisation. This platform is used for optimizing the use of maritime expertise and (wave and tidal) test facilities between the industry, universities and government.
Mermaid has received the concession for their plans to build a combined wind and wave energy park in the 7th and most northern part of the Domain Concession Zone. THC Mermaid is a partnership that consists of 65% of Otary RS and 35% of Electrabel (GDF SUEZ). Otary is a collaboration of Aspiravi, Electrawinds, Nuhma, Power@Sea, Rent-A-Port, Socofe and SRIW Environment.
In the tidal sector, the Belgian company DBE (Deme Blue Energy) has an agreement (together with DP marine Energy) for lease from the Crown Estate for 2 big tidal turbine projects with only 60 km distance in between: 30 MW in Islay (8 km off the tip of the Rhinns) and 100 MW in Fair Head (www.deme.be).

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 2017. 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

TRACEY KUTNEY *Natural Resources Canada*

INTRODUCTORY NOTE

The Canadian marine renewable energy sector progressed steadily in 2015. The province of Nova Scotia passed sector-specific legislation, the Fundy Ocean Research Centre for Energy (FORCE) announced the development of a 5th berth at the in-stream tidal demonstration site, new monitoring instruments for accurate tidal current and turbulence measurements were developed, and international collaborative R&D projects between Canada and the United Kingdom were announced.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

Canada's Marine Renewable Energy Technology Roadmap establishes targets for the Canadian sector, contributing to projects totalling 75 MW by 2016, 250 MW by 2020 and 2 GW by 2030 for installed in-stream tidal, river-current and wave energy generation.

Many tidal activities are taking place on the Atlantic coast, particularly in the province of Nova Scotia in the Bay of Fundy. 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 market-competitive technologies and an industrial sector. Released in 2012, the Strategy sets goals to develop marine renewable energy legislation, implement a research and development plan and has a target of licensing 300 MW of commercially-competitive in-stream tidal electricity generation. This past year saw the delivery of the legislation and progress on research and development activities.

LEGISLATION AND REGULATORY FRAMEWORK

At the federal level, the Department of Natural Resources Canada, under the Marine Renewable Energy Enabling Measures programme, continues to take a lead role towards the development of a policy framework for administering marine renewable energy activities in the federal offshore. This policy framework will provide direction to the federal Government on the potential development of a comprehensive legislative framework for administering marine renewable energy projects in the federal offshore.

The Government of Nova Scotia passed the Marine Renewable Energy Act in 2015, which applies to Nova Scotia's Bay of Fundy and the Bras d'Or lakes. This legislation ensures that marine renewable energy projects, including in-stream tidal, tidal range, offshore wind, wave and ocean currents, are developed in a manner that respects the environment and the interests of local communities; ensures increased consultation and provides for the safe, responsible and strategic development of the industry; and establishes a licensing and permitting system for the placement of marine renewable energy generators in those areas.

MARKET INCENTIVES

From 2011 to 2015, the province of Nova Scotia had two opportunities for in-stream tidal energy developers to receive Feed-in Tariffs (FITs)—one for community-owned, smaller scale developments under the Community Feed-in Tariff (COMFIT) programme (at a rate of 65.2 cents/kilowatt hour) and another for larger scale developmental projects (ranging from 37.5 cents/kilowatt hour to 57.5 cents/kilowatt hour). The Province's Electricity Plan, released in November 2015, replaces guaranteed FITs with a fair, competitive process for renewable energy technologies; however, existing FIT approvals will be able to proceed.

The Fundy Ocean Research Centre for Energy (FORCE) is Canada's research centre for in-stream tidal energy, located in the Bay of Fundy, Nova Scotia. FORCE provides four berths (project sites) to host technology developers, with electrical infrastructure to deliver power to the grid. In December 2014, four developers with projects at FORCE received FIT approvals, totalling 17.5 MW to be developed at the FORCE site:

- Minas Energy (4 MW)
- Black Rock Tidal Power (5 MW)
- Atlantis Operations Canada, in partnership with DP Energy (4.5 MW)
- Cape Sharp Tidal Venture, a joint venture between Emera and OpenHydro/DCNS (4 MW)

Each of the developers at FORCE has received approval for the FIT, which allows them to enter into a 15-year power purchase agreement with Nova Scotia Power, the provincial electric utility. Cape Sharp Tidal Venture is expected to deploy their first turbines in the Bay of Fundy in early 2016.

In December 2015, Nova Scotia announced an agreement with Irish-based DP Energy to install a 4.5-MW in-stream tidal energy project at a 5th berth at the FORCE test site. DP Energy has plans to install three 1.5 MW Andritz Hydro turbines.

In addition, Fundy Tidal Inc. has received three approvals under the Nova Scotia COMFIT programme, which allows local community groups to connect small scale in-stream tidal devices under 500 kW to the electrical grid at the distribution level for over a 20-year contract.

The Government of Nova Scotia has committed to limiting the impact on ratepayers, due to the FIT, to two per cent.

PUBLIC FUNDING PROGRAMMES

To date, Canada's main public funding programmes supporting national research, development, and demonstrations (RD&D) are from federal programmes administered through the Office of Energy Research and Development at Natural Resources Canada. Canada has committed approximately $37 million to marine renewable energy RD&D since 2010. In addition, 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-current and wave energy technologies.

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

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 are estimated be a value of approximately $3.5 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.

MARINE SPATIAL PLANNING POLICY

The *Oceans Act*, *Canada's Oceans Strategy*, and the *Policy and Operational Framework for Integrated Management of Estuarine, Coastal and Marine Environments in Canada* provide the policy framework and guide Canada's approach to oceans management. The approach is centred on the principle of Integrated Management (IM), which seeks to establish decision-making structures that consider both the conservation and protection of ecosystems, while at the same time providing opportunities for creating wealth in oceans related economies and communities.

IM efforts in Canada are being undertaken through an area-based approach that supports marine planning, management and decision-making at appropriate spatial scales, from regional to site-specific. In Canada, IM is implemented through a regional approach. Therefore, it is important to determine the key social, technical, legislative/policy and political challenges to advancing spatial and temporal planning at a regional level.

Network development is underway in all three of Canada's oceans, and is an example of conservation work undertaken as part of Canada's approach to oceans management. A network is a collection of individual marine protected areas (MPAs) and other effective area-based conservation measures, in different geographic locations, designed to work together in order to fulfill ecological objectives more effectively and comprehensively than a group of individual sites could do alone. The *National Framework for Canada's Network of*

Marine Protected Areas provides overarching direction for this work, and points to the importance of using existing IM decision-making structures.

PERMITTING AND LICENSING PROCESS FOR OCEAN ENERGY PROJECTS

A key piece to Nova Scotia's *Marine Renewable Energy Act* is the creation of a licensing and permitting system that will oversee the development of marine renewable energy projects. Any generator proceeding in a priority area without an approval will be in violation of the Act. A license will allow a project developer to carry out the business of extracting energy within a 'marine renewable-electricity area' (i.e., an area designated for development) through single or multiple devices. A permit will be issued to a temporary deployment of a device for the purposes of testing and demonstration. This system will ensure that projects proceed only after undergoing a thorough review by the Government and subject to effective Government oversight and monitoring.

TEST SITES

TIDAL CURRENT TURBINE TEST SITE

FORCE reached a major milestone in 2014: the installation of the underwater power cables. The four cables laid along the sea floor of the Minas Passage give FORCE the largest transmission capacity for tidal power in the world. With a combined length of 11 kilometres, the four cables have a total capacity of 64 MW at peak tidal flows, equivalent to the power needs of 20,000 homes. Each 34.5 kilovolt cable, together with its reel, weighed over 100 tonnes.

In 2015, following the announcement that all four FORCE developers received approval through Nova Scotia's FIT programme, FORCE began feasibility and impact studies, approvals, permitting, and electrical design work to expand their onshore electrical infrastructure to accommodate up to 20 MW; to allow small turbine arrays to connect to the electricity grid.

Cape Sharp Tidal Venture (CSTV), a berth-holder at FORCE, had two successful operations in 2015: the installation of a subsea cable at the FORCE test site, and the launch of the Scotia Tide deployment barge. The cable is an interconnection hub that will connect CSTV turbines to the existing 16MW subsea FORCE export cable. Not only was the operation safely executed, but it is the first project component to be deployed, and the only system of its kind in the world. CSTV also deployed 300 metres of cable to its berth site at FORCE.

CSTV's barge, christened The Scotia Tide, took her maiden test voyage around the Pictou Harbour in December 2015. The unique, catamaran-style vessel is the largest heavy lift capacity barge in Atlantic Canada. The 64 metres long, 37 metres wide, 650-tonne barge has a 1,150-tonne carrying capacity. Purpose-built for deployment and recovery operations, it is equipped with three heavy-lift winches that give it a unique capacity to lower and raise turbines from the sea floor.

Fundy Advanced Sensor Technology (FAST) platform

To support the deployment of the turbines, FORCE has completed construction of two underwater platforms to host a suite of resource and environmental monitoring instruments, called the Fundy Advanced Sensor Technology (FAST) platforms. Both platforms are now in sea trials.

As part of FAST, FORCE has completed phase one of the Vectron project, with partners Nortek Scientific and Dalhousie University, which will offer high resolution current velocity and turbulence data at turbine hub height. FORCE has also conducted a survey of the FAST data cable, establishing useful methods and equipment for monitoring and maintaining subsea assets. FORCE has also integrated shore-based monitoring systems, including X-band radar, a meteorological tower and a tide gauge, providing a multi-dimensional understanding of the operating environment, in real-time.

FORCE is collaborating with Ocean Networks Canada (ONC) to support the FAST programme by enhancing the accessibility of its data to the public, scientists and developers around the world. Much of the data collected is accessible online, including a time-lapse video from the previous day: http://fundyforce.ca/visit/live-video/.

A part of FORCE's core mandate is designing a new environmental effects and monitoring programme to track effects of turbines on the environment.

RIVER CURRENT TURBINE TEST SITE

The Canadian Hydrokinetic Turbine Test Centre (CHTTC) in Manitoba is operating using its dedicated infrastructure in the Winnipeg River to test river current technologies. In 2015, CHTTC deployed and tested 4 turbines, supplied by 3 technology developers. CHTTC applied the IEC TC114 standard 62600-200 for the performance evaluation of tidal turbines for two of the turbines. During this test, the incoming flow to the turbines was measured using Acoustic Doppler Velocimetres (ADVs) and Acoustic Doppler Current Profilers (ADCPs) and the load on the mooring line was measured simultaneously.

In 2014, at CHTTC, more than 80 fish were tagged and released into the Winnipeg River. In 2015, data collected from receivers along the river and near turbines were used to analyse the effect of river current turbines on the activities of the fish. Preliminary data analysis indicates no significant effect on the fish behaviour due to turbine operation. In addition, a 48-hour underwater camera observed the interactions between a 5 kW river current turbine and passing fish; it was found that none of the fish in the vicinity of the project interacted with the turbine.

Other projects conducted by CHTTC in 2015 included: improving satellite imaging for river kinetic site selection; site assessment near Sagkeeng First Nation resort for river kinetic turbine deployment; creating a comprehensive map of off-grid communities with access to hydrokinetic resources; testing, calibrating and improving marine measurement equipment; and the design and development of innovative tools for flow measurement and other marine applications.

For 2016, CHTTC intends to test turbines according to international standards and through third party relevant certifications.

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. In conducting this work, a former fish processing facility has been renovated and provides space for the farm, the computer control and data collection equipment, a laboratory, and workshops. 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 30m) available within 1.5 km from shore. The site has collected weather and wave environment data, over three years. With a dedicated wharf and slipway, the site is ideal for the testing and demonstration of wave energy converters (WEC) and other surface and sub-surface structures in an energetic nearshore environment, as well as the development of associated instrumentation and sensor systems. To date, 3 WEC developers, 2 instrument manufacturers and a coatings company have expressed interest in evaluating their technology at WERC.

Scale model testing of the CNA wave energy converter water pump is completed and the deployment of a full scale prototype at sea in Lord's Cove is expected in 2016. This approximately 10 tonne wave energy converter is designed as a robust, low technology point absorber conceived to deliver a high volume of water to shore. Once there, the water can be used in industrial, aquacultural and electrical generation applications, without exposing more complex technology to extreme ocean conditions.

RESEARCH & DEVELOPMENT

Several universities across Canada are involved in the marine renewable energy sector. Acadia Tidal Energy Institute (ATEI) out of Acadia University focuses on projects that seek to ensure that tidal energy development is sustainable through risk reduction and informed decision-making. Over the past year this work involved: 1) Developing the Nova Scotia Tidal Energy Atlas, an interactive web-based mapping application that makes tidal energy related spatial information readily accessible to the public, and is planned for public release in February 2016; 2) Leading the analysis of the three Digby passages, measuring and modelling the turbulence in the tidal flows; 3) Assessing different stakeholders' community engagement strategies in Nova Scotia and to what extent these strategies support social acceptance of tidal energy development; 4) Conducting work to advance acoustic environmental sensors and software for the detection of fish and marine mammals at and near tidal energy turbines; 5) Gathering the insights of executives and senior managers in the tidal energy industry both locally and internationally to understand the strategic decision-making regarding the timing of commercial scale tidal energy investment, and 6) Developing a Tidal Energy School Outreach Programme that brought tidal energy hands-on activities and information into Nova Scotian classrooms for over 300 students in 2015.

Wave energy research in Canada continues to be driven by the West Coast Wave Initiative (WCWI) out of University of Victoria's Institute for Integrated Energy Systems (IESVic). 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 an 11-year hindcast and a 48-hour forecast. The WCWI works to evaluate wave energy converter designs and control system configurations with a number of national and international technology developers, including Resolute Marine Energy, Carnegie Wave Energy, Ocean Energy Ltd, Seawood Designs and Accumulated Ocean Energy. Hourly power production estimates for future wave energy converter farms off the British Columbia coast, created by combining the detailed wave resource and device performance characteristics, are then simulated into the BC Hydro electrical grid. This allows for the identification of WEC farm locations which maximise utilization of the produced power and require the lowest capital investment on behalf of local utilities. Additionally, WCWI researchers, in collaboration with Sandia National Labs, are developing a novel wave propagation code allowing for the implementation of WEC farms within SWAN; this will allow for higher resolution predictions of WEC farm power output and far field disturbance effects.

TECHNOLOGY DEMONSTRATION

OPERATIONAL PROJECTS

New Energy Corp. installed their 5 kW EnviroGen vertical axis turbine in Ringmo, Dolpa, Nepal, in the spring of 2014. The site is very remote – it is a 3-day walk to the nearest road, and all components needed to be carried in by hand. The system operated for four solid months at capacity in 2014. Ringmo closes down each fall, but it re-opened again in the spring of 2015, at which time the unit was put back into operation.

In the fall of 2015, New Energy Corp. installed two of their 5 kW EnviroGen turbines in Myanmar in order to provide year- round power for a school. The two floating demonstration systems were installed in a river adjacent to the school. The turbines have been operating since.

New Energy Corp. installed their 5 kW EnCurrent vertical axis turbine at the CHTTC in September 2014 primarily to test a patented fully-submersible bearing. The test was a resounding success, and this bearing design has already been incorporated into the commercial product design. Testing continued in 2015 on various aspects of the mechanical design as well as control system enhancements for both standalone and grid connected applications.

New Energy Corp. began the civil works construction on their Canoe Pass, British Columbia project, in June 2014. Canoe Pass is a 500 kW tidal demonstration project on Vancouver Island. All permitting and regulatory approvals are in place for the project. Part of the causeway between two islands will be removed to install two 250 kW turbines. The turbine installation is scheduled for late 2016.

Mavi Innovations first tested their Mi1-20 kW floating ducted crossflow turbine at the CHTTC in November 2014 over the course of two weeks in severe winter conditions. The team learned first-hand about the challenges of designing and operating turbines in a Canadian winter environment (-30 °C air temperatures). The Mi1 was redeployed at the CHTTC in July 2015 and underwent a series of performance tests over the course of 4 months. In addition to commissioning the unit, Mavi worked with CHTTC staff and Dynamic Systems Analysis to measure mooring loads and turbine performance in order to validate IEC-TC114 standards currently under development.

Floating ducted crossflow turbine (Mavi Innovations)

Instream Energy Systems has received approval by the US Bureau of Reclamation to extend its lease at the Roza Canal site in Washington State. Instream has used this site since 2013 as an infield pilot site to test system updates and upgrades. Instream plans on adding more turbines as well as connecting to the grid. In addition, Instream has received the European Union Eureka Label and Canadian Government funding from the National Research Council for its Marine Floating Platform Design Project in collaboration with UK-based IT Power. Instream continues to work with BAE systems and is presently developing its next generation turbine.

Instream Energy Systems

Idénergie installed a river turbine in Quebec during 2015 to power a welcome centre for a fish and hunting ground. The turbine was used in high-velocity flows of over 3.5 m/s with success. A demonstration was also performed in a river at Jasper National Park, in the province of Alberta, in collaboration with Parks Canada. Towards the end of the year, a turbine was installed to power an off-grid residence during the winter. Recent upgrades to the river turbine bring its nameplate capacity to 1 kW and permit the inter-connection of multiple turbines together.

Mermaid Power, awave energy point absorber, has completed tank tests to prove the viability of their Power Take-Off (PTO) mechanism, as well as their tidal compensator system. In December 2015, they deployed their Neptune 3 device first to the maritime museum in Vancouver harbour and secondly to a nearshore testing location off Keats Island in British Columbia. The Neptune 3 device is 16,000 kg with a 3,500 kg motive float. The device will undergo grid power connectivity testing under the BC Hydro net-metering programme, where it will run a series of tests to determine the actual empirical wave energy force acting to move the motive float vertically in various sized waves, and show real time video surveillance of underwater activities, PTO action, electric meter action, and overall situational activities.

Neptune 3 device (Mermaid)

Accumulated Ocean Energy Inc., a wave energy point absorber buoy, tested their 1/12 scale system in the Sooke Basin, on the south end of Vancouver Island in southwestern British Columbia, in 2015.

Accumulated Ocean Energy 1-12 scale device testing in Sooke Basin - Vancouver Island

Grey Island Energy, with their "SeaWEED" wave energy surface attenuator, conducted testing at the Canadian National Research Council's Ocean Engineering Basin. The 1/16 scale SeaWEED prototype was able to efficiently capture and convert wave energy, and the physical model matched the numerical model, which informed how much power the device could produce at a full scale. The results exceeded expectations.

1/16 scale SeaWEED device (Grey Island Energy)

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.

PLANNED DEPLOYMENTS

The province of Nova Scotia anticipates deployment of 22 MW of large scale in-stream tidal energy to be deployed in the Bay of Fundy over the coming 3-5 years. The first project scheduled for deployment is Cape Sharp Tidal Venture, which is expected to deploy its first turbines in the spring of 2016.

Working with a consortium of industry and academic partners, **Fundy Tidal** has continued to advance their COMFIT small scale tidal energy projects in Grand Passage, Petit Passage, and Digby Gut, Nova Scotia. Fundy Tidal is progressing through the Nova Scotia Power interconnection process for their Digby Gut project and is working towards a financial close for all projects.

New Energy Corp. has received preliminary approval to supply a 25 kW EnviroGen Power Generation System to a First Nation community in Manitoba. Approvals are in place, and fabrication is scheduled to begin in early 2016. Installation of the system is scheduled for the summer of 2016.

In 2016, **Mavi** plans to integrate the Mi1 turbine along with battery storage and possibly solar into an existing diesel grid to power a remote lodge in British Columbia. The objective of this project is to assess the feasibility of using tidal power to offset the use of diesel fuel by off-grid coastal communities.

Water Wall Turbine plans on testing their 500 kW, full size, in-stream tidal demonstration turbine in the Fraser River, Vancouver, in January 2016, before they deploy the device at the Dent Island test site. The Dent Island project comprises a microgrid, and the testing of the microgrid components will take place in March 2016. The design and construction of the microgrid components is underway.

Instream Energy Systems has secured a location in the northwest USA for a marine trial in early 2017. The trial will integrate a number of turbines on a single floating platform with an output of approximately 100 kW. In addition, Instream has been selected by the University of New Hampshire to provide a single 25 kW turbine for "the Living Bridge Project". This project will harness energy from the tides flowing under the bridge and is scheduled for delivery in late 2016.

Idénergie will install 6 river turbines and 72 solar panels to power an outfitter establishment in north eastern Canada, in 2016. An additional deployment of 10 turbines is planned for the summer at Banff and Jasper National Parks in the Canadian Rockies, in the province of Alberta. The turbines will allow Parks Canada to power various off-grid campgrounds and facilities.

Mermaid Power's Neptune 4, a wave energy point absorber, is expected to be deployed on the west coast of Vancouver Island in late 2016 to test gale force storm survivability of their point absorber system – they are looking for a deployment site in the Sooke-Shirley-Jordan River-Port Renfrew area.

In 2014, **Jupiter Hydro** successfully demonstrated both their 36" diameter Delta unit, and their 42" diameter 3EC42 unit, helical screws turbines, at the CHTTC. Jupiter's two prototypes have cleared the path to commercialization. Jupiter Hydro is currently planning on deploying their 1 MW unit at EMEC in late 2016.

In the 2nd quarter of 2016, **Accumulated Ocean Energy Inc.**, a wave energy point absorber buoy, will establish an office in Cork, Ireland. A 1/4 scaled system will follow at the Galway Bay Smart Bay Wave Test Site. In 2015, Accumulated Ocean Energy Inc., partnered with T'Sou-ke Economic Development Limited to establish the T'Sou-ke Ocean Energy Limited Partnership (TOE LP), which is aimed at pursuing business opportunities located in the traditional territory of T'Sou-ke Nation. The first of the projects proposed by the newly formed TOE LP will be the installation of a test system off the shores of the T'Sou-ke traditional territory.

In 2016, **Grey Island Energy** is planning to deploy a 1/4 scale prototype of their surface attenuator, the SeaWEED device, in Scotland, in conjunction with their Scottish office and other potential UK partners.

OTHER RELEVANT NATIONAL ACTIVITIES

INTERNATIONAL INITIATIVES

To further activity under the Canada-United Kingdom Joint Declaration, a Memorandum of Understanding (MoU) between Nova Scotia, the Offshore Energy Research Association of Nova Scotia (OERA), and the United Kingdom's Technology Strategy Board (TSB, now InnovateUK) was signed in March 2014 to encourage joint research to develop new and innovative technology for high-flow tidal environments. As a result of this MoU, a joint research fund was launched and 2 projects were announced in 2015:

- *Emera, OpenHydro, Ocean Sonics, Acadia University, Seam Mammal Research Unit (SMRU) Canada, and from the UK, Tritech, and SMRU*: the Project will deliver an innovative system using both passive and active acoustic sensor technologies to improve 'real-time' tracking of fish and mammals at tidal sites in the Bay of Fundy.
- *Rockland Scientific, Dalhousie University, Black Rock Tidal, and from the UK, FloWave TT, European Marine Energy Centre (EMEC), and Ocean Array Systems*: Development of a new sensor system to measure the impact of turbulence on tidal devices. The project results will be used to improve turbine designs and operation performance, as well as assessment of installation sites. This is a EUREKA-designated project.

INTERNATIONAL ACTIVITIES

Canada has been actively engaged in the standards development process for marine renewable energy since the inception of IEC TC114 in 2007. The Canadian committee consists of a volunteer group of 32 technical experts from industry, academia and federal and provincial governments. Canadian experts are working on all active project teams within TC114, including the 6 published standards, as well as the 9 other standards currently in the drafting stage (https://webstore.iec.ch/searchform&q=iec%2062600). Canada continues to engage in research specifically targeted towards addressing the knowledge gaps encountered during standards development. The areas of research included are: environmental noise measurement; river converter power extraction and resource assessment; ice and debris impact for river and tidal site; reliability and load factor guidelines and long term wave energy converter performance.

INTER-PROVINCIAL INITIATIVES

Nova Scotia and British Columbia renewed their partnership to advance Canada's marine renewable energy sector through the signing of a Memorandum of Understanding in July 2015. The Memorandum of Understanding outlines key priorities, including partnering on research and technology development, and sharing information and best practices in regulation and permitting. The Memorandum represents a commitment from both provinces to further develop the tidal resource in the Bay of Fundy and wave-generated energy on British Columbia's west coast.

PROVINCIAL INITIATIVES

In April 2015, Nova Scotia's Offshore Energy Research Association (OERA) released the Value Proposition for Tidal Energy Development in Nova Scotia, Atlantic Canada and Canada, to determine the potential of building a tidal industry in Canada. The study examines the economic potential that could be realized over a 25-year period to 2040. It found that the new industry could contribute up to $1.7 billion to Nova Scotia's gross domestic product (GDP), create up to 22,000 full time positions and generate as much as $815 million in labour income. This opportunity is significant as there will be spill over effects in the Atlantic region and elsewhere in Canada.

OTHER CONFERENCES

The Marine Renewables Canada Annual Conference will be held in the fall of 2016.

CHINA

XIA DENGWEN *National Ocean Technology Centre*

INTRODUCTORY NOTE

In 2015, the State Council released the "Opinions on Further Deepening the Reform of the Electric Power System", emphasizing the improvement of the proportion of renewable energy and distributed energy in the electricity supply, to guarantee the full purchase of electricity generated by renewable energy. The supporting objects of the "Interim Management Measure for Renewable Energy Development Special Fund" released by the Ministry of Finance (MOF) enlarged from the utilization and development of renewable energy to both renewable energy and new energy.

The "Renewable Energy Technology Development Programme (2016-2020)" developed by the Ministry of Science and Technology (MOST) has been reviewed by the National Advisory Committee, considering two key missions for Marine Renewable Energy (MRE). The National Energy Administration (NEA) is developing the "Renewable Energy Development Plan (2016-2020)", including the "Ocean Energy Development Strategy" developed by the National Ocean Technology Centre (NOTC), and the State Oceanic Administration (SOA). The new round of the special funding programme for MRE (SFPMRE) sponsored by MOF and SOA initiate to support 3 projects.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The "Renewable Energy Technology Development Programme (2016-2020)", developed by MOST since 2014, was reviewed by the National Advisory Committee in September 2015, considering two key missions for MRE, that is, the fundamental study on MRE technologies and key technologies R,D&Demo, such as the design and manufacture of MWs tidal current energy turbine, modular design and manufacture of 100 kWs wave energy converters.
The "Renewable Energy Development Plan (2016-2020)", developed by NEA in 2015, is in the support of China Renewable Energy Scale-up Programme (CRESP) funded by the World Bank, including the "Ocean Energy Development Strategy" developed by NOTC, SOA, laying emphasis on improving the MRE technology readiness level and enhancing the application of MRE in remote islands and offshore areas.

REGULATORY FRAMEWORK

In April 2015, the "Interim Management Measure for Renewable Energy Development Special Fund" was released by MOF, supporting the demonstration of key technologies and industrialization, public platform construction, scale development, and integrated utilization of renewable energy and new energy.

MARKET INCENTIVES

In March 2015, the "Opinions on Further Deepening the Reform of the Electric Power System" was released by the State Council, emphasizing the improvement of the proportion of renewable energy and distributed energy in the electricity supply, to guarantee the full purchase of electricity generated by renewable energy.

PUBLIC FUNDING PROGRAMMES

In June 2015, RMB 100 million financial funds of SFPMRE were granted to support the 3 projects, including the MWs Tidal Current Energy Demonstration Project in Zhoushan, Independent Tidal Current Energy Demonstration Project On Islands, and Construction of Floating Testing Platform for National MRE Test Site.

MARINE SPATIAL PLANNING POLICY

In March 2012, the "National Marine Functional Zoning (2011-2020)" was approved by the State Council. Marine renewable energy functional zones were demarcated in the provincial marine functional zoning systems.

PERMITTING AND LICENSING PROCESS FOR OCEAN ENERGY PROJECTS

The sea use for MRE projects in sea trial and demonstration should be consented by local oceanic agencies, maritime agencies and fishery agencies; sometimes it should also be negotiated with military sectors.

TEST SITES

For the national small scale test site in Weihai Shandong province, the 5 km^2 sea area and 30,000 m^2 land area were authorized in November 2014. In January 2015, to provide a foundational reference for the detailed design of the low speed tidal berth, a supplementary investigation was carried out. Additionally, a marine environmental monitoring buoy for the test site was deployed and has been in operation since May 2015.

For the national tidal energy full scale test site in Zhoushan Zhejiang, 3 test berths and 6 demonstration berths have been designed. In June 2015, the construction of demonstration project was initiated by China Three Gorges Corporation with the sponsorship of the new funding round by SFPMRE.

For the national wave energy full scale test site in Wanshan Guangdong, 3 test berths and 6 demonstration berths have been designed. The project feasibility study initiated in 2014 by China Southern Power Grid has been completed.

RESEARCH & DEVELOPMENT

TIDAL CURRENT ENERGY

Zhejiang University (ZJU): **ZJU turbines** (60kW/120kW) are semi-direct drive floating H-axis turbines. The ZJU turbines have been deployed near Zhairuoshan Island for sea trial since May 2014; the amount of electricity generated has accumulated to more than 23MWh till October 2015, with the maximum instantaneous output power of 118kW and the conversion efficiency of 0.371. MOST inspected and concluded the project on 27 October 2015. A new 300 kW turbine based on ZJU turbines will be assembled and tested in 2016 by Guodian United Power Technology Co. and ZJU.

Zhejiang Zhoushan LHD New Energy Corporation Limited (LHD): **LHD L-1000 turbines** (4×300kW) are fixed V-axis turbines, with cut-in speed of 0.7m/s and cut-out speed of 4m/s. The modular turbines have been assembled and will be deployed on Xiushan Island in January 2016.

DaLian University of Technology (DLUT): **DLUT turbine** (15 kW) is a V-axis turbine. The DLUT turbine has been deployed near Changshan Island for sea trial since 2013. The maximum output power is 8 kW, and the conversion efficiency is 0.25. The project was concluded in May 2015.

WAVE ENERGY

Guangzhou Institute of Energy Conversion (GIEC) of Chinese Academy of Sciences (CAS): By April 2014, **Sharp Eagle I** (10 kW) floating wave energy converter had been running near Wanshan Island for nearly 6000 hours accumulatively, with the total conversion efficiency of 16.76%. Based on Sharp Eagle I, China Shipping Industry Co. and GIEC jointly developed a 100 kW **Sharp Eagle Wanshan** converter, the new converter has been deployed for test since November 2015.

Jimei University (JMU): **Jida I** (10 kW) is a floating wave energy converter composed of 10 oscillating buoys, has been deployed near Xiaodeng Island for sea trial for more than 5000 hours till April 2015. The maximum output power is 3.6kW, with the total efficiency (synergy with wind turbine) of 15%. The project was concluded in October 2015.

Zhejiang Ocean University (ZJOU): **Haiyuan I** (10 kW) is a floating converter with 3 oscillating buoys, and had been deployed for sea trial on Zhoushan Islands for more than 165 days till May 2014. The total efficiency is about 16.4%. The project was concluded in May 2015

Shandong University (SDU): **SDU WEC** (120 kW) is a floating converter. The first 120 kW has been deployed in sea trial for 5 months since November 2012 and retrieved for upgrade. Three new converters were assembled in September 2015 and will be deployed in Weihai test site, Shandong for test.

TECHNOLOGY DEMONSTRATION

OPERATIONAL PROJECTS

Jiangxia Tidal Power Plant: With the support of SFPMRE in 2012, the upgrading project (#1 turbine upgrade) was completed in August 2015; the installed capacity of Jiangxia Plant has increased to 4.1 MW. The new turbine (#1) has been operating for more than 1000 hours and generated electricity of 326MWh until October 2015.

PLANNED DEPLOYMENTS

Dawanshan Island Isolated Hybrid Power Demonstration Station: The station comprises a 300 kW wave energy device (Eagle II), 100 kW wind turbines and 300 kW solar panels. The Eagle II wave energy device has been assembled and will be deployed after the manufacture of the mooring system.

Shengshan Island Isolated Hybrid Power Demonstration Station: The station comprises 300 kW wave energy converters (FLB), 150 kW wind turbines, 50 kW bioenergy devices and 25 kW solar heat cells. In October 2014, two 100kW converters were deployed for a 3-month test, and then were retrieved after the damage of hydraulic pipes. The wave energy converters have been deployed for sea trial since December 2015.

Daishan Tidal Current Technology Demonstration Station: the Haineng III (2×300 kW) floating V-axis turbines have been deployed for sea trial in Guishan Channel, Zhejiang, since December 2013, with total conversion efficiency of nearly 30%. In August 2014, Haineng III suspended operation for the breakage of the mooring system. In December 2015, Haineng III was deployed for sea trial in Guishan Channel after the restoration of the mooring system.

OTHER RELEVANT NATIONAL ACTIVITIES

4th CHINA MARINE RENEWABLE ENERGY CONFERENCE

The 4th China Marine Renewable Energy Conference (CMREC) hosted by NOTC and the Administrative Centre for Marine Renewable Energy (ACMRE) was held on 28 May 2015 in Weihai, Shandong Province. The theme of the annual conference was “strengthen planning, scale development, lighting the blue energy”. More than 210 participants from governments, universities, institutes, industries and stakeholders participated in the conference.

DENMARK

KIM NIELSEN *Ramboll*

INTRODUCTORY NOTE

Wave energy is estimated to be able to contribute with power equivalent to 15% of the Danish electricity consumption and create opportunities for export of components, products and jobs. Several different wave power systems at different scales are being developed and tested.

The Danish wave energy developers have created the "Partnership for Wave Power" and prepared a strategy for development of wave energy in 2012 followed by roadmaps in 2015, which aim at Danish and international commercial success for the wave power sector by 2030. The funding required to support the development in Denmark is estimated in the order of DDK 5-20 million /year. The partnership meets twice a year and share their experience accumulated from R&D and tests in the sea.

DanWEC test site is being developed with Greenlab funding. Two wave rider buoys have been launched and a seabed survey has been carried out over an area in the sea south-west of the harbour. This area has been accepted by authorities for test purposes, and at the moment the wave energy system Wave Piston has a permit to test in this area and deployed their anchoring system during the summer of 2015.

The Danish wave energy sector is involved in co-operate projects funded by European Union (EU) as well as international collaborations.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

In 2015, the Partnership for Wave Power published a set of roadmaps for development of wave power, which aim at Danish and international commercial success on the wave power sector by 2030. The roadmap work has been funded by the Danish Energy Agency.

PUBLIC FUNDING PROGRAMMES

National energy development programmes such as EUPD, Energinet.dk and the Danish Strategic Research Council are able to fund development of wave energy, as well as other sources.

MARINE SPATIAL PLANNING POLICY

A new law for the use of marine space has circulated for comments at the end of 2015. The purpose of the law is to establish fair rules for the use of marine space in addition to the traditional sectors such as fisheries and transport.

It concerns economic, social and environmental conditions, as well as safety aspects in order to support sustainable development and growth in the maritime sector, using an ecosystem-based approach, and the promotion of coexistence of different relevant activities and users:

- 1 energy sector of the sea,
- 2 maritime transports,
- 3 fisheries and aquaculture,
- 4 extraction of raw materials at sea, and
- 5 the conservation, protection and improvement of the environment, including resistance for consequences of climate change.

PERMITTING AND LICENSING PROCESS FOR OCEAN ENERGY PROJECTS

Wave energy converters to be tested at DanWEC or at other locations in Danish waters will typically receive a temporary permit for deployment over the testing period for one or two years. Such permit can be obtained by filling an application to the Danish Energy Agency that will process the application.

TEST SITES

The experience from prototype testing at DanWEC is very important in order to achieve the long term goals of reliable wave energy conversion. DanWEC includes two sites – a benign site in Nissum Bredning which has a maximum wave significant wave height H_{smax} of about 1 meter – and an exposed site at Hanstholm with H_{smax} up to 6 meter. In 2015, the exposed area was defined as shown on the figure below – it covers from 10 – 28 meter water depth in a distance of about 2 – 3 km from Hanstholm harbour.

DanWEC Test area south of Hanstholm harbour covers an area of 2800 m x 1600 m

RESEARCH & DEVELOPMENT

Mooring solutions for large wave energy converters is a project funded by EUDP. The project is co-ordinated by Aalborg University and four large wave energy converters are being investigated under the project.

All Danish wave energy developers are participating in the Partnership for Wave Power; this partnership includes WaveStar, Floating Power Plant, Crestwing, Leancon, WaveDragon,Weptos, WavePlane, Joltec, Resenwave and KNSwing as illustrated in the figure below. Denmark is involved in co-operate projects under EU and the standardisation work under IEC.

Denmark is involved in co-operate projects under EU and the standardisation work under IEC

TECHNOLOGY DEMONSTRATION

OPERATIONAL PROJECTS

Wave Piston

http://www.wavepiston.dk

In 2015, Wave Piston installed their system technology at DanWEC in order to test new innovative lightweight, low-cost components and solutions to harvest wave power. The technology includes a number of submerged plates on a string stretching between two anchor buoys hold in place by to anchors – the plates will surge and react against each other activating pumps producing pressurized water.

Leancon

http://www.leancon.com

Leancon is a V-shaped structure incorporating 52 OWC chambers. The design and manufacturing of a 24-meter wide scale 1:10 model has been completed more or less single handed by the inventor Kurt Due who launched the WEC in the sea in July 2015. The project has been funded by Energinet.dk. After a period of six month with four significant storms and exposure to the harsh environment, the structure has been taken to shore for inspections and processing of experience and impact on structure and moorings, before further testing and measurements are undertaken.

The 24 meter long Leancon system was installed in 2015 at the test site in Nissum Bredning

Crestwing

http://crestwing.dk/index.html

Crestwing consists of two hinged pontoons with a mechanical PTO moored using a flexible three point mooring system developed in co-oporation with Seaflex to minimize the footprint of the installation on both the sea surface and the seabed. The turret anchor solution allows the WEC to turn 360° and has full automatic connection and disconnection.

Crestwing prototype 10 meter wide 30 meter long 2,5 meter high with a weight of 60

PLANNED DEPLOYMENTS

WaveStar (http://wavestarenergy.com), has announced successful Horizon 2020 contract negotiations and signed a consortium and grant agreement to produce and test the first full scale 1 MW Wavestar. The consortium behind the EU application consists, among others, of STX, IFP EN, DNV and Aalborg, Gent and Cantabria Universities.

OTHER RELEVANT NATIONAL ACTIVITIES

The Danish Partnership for Wave Energy arranges biannual meetings and workshops for the members and other interested parties. The workshops are conducted to allow for a transfer of experience gained by the individual developers as a basis for achieving the long term goal of developing reliable and cost-effective wave energy solutions.

GERMANY

JOCHEN BARD AND FABIAN THALEMANN *Fraunhofer IWES*

OCEAN ENERGY POLICY

The revised 2012 version of the Renewable Energy Sources Act, adopted in 2011 and in force since 1 January 2012, is designed to facilitate a sustainable development of energy supply in Germany, to reduce the costs of energy supply to the national economy, to conserve fossil fuels, and to promote the further development of technologies for the generation of electricity from renewable energy sources.

To achieve this purpose, the Act aims to increase the share of renewable energy sources in electricity supply to at least 35% by 2020 and 50% by no later than 2030; 65% by 2040 and 80% by no later than 2050, and to integrate these quantities of electricity in the electricity supply system.

The following definition has been adopted: "renewable energy sources" shall mean hydropower, including wave power, tidal power, salt gradient and flow energy, wind energy, solar radiation, geothermal energy, energy from biomass, including biogas, biomethane, landfill gas and sewage treatment gas, as well as the biodegradable fraction of municipal waste and industrial waste (source: Act on granting priority to renewable energy sources, 1 April 2012). The tariff paid for electricity generated from hydropower, which includes the above mentioned ocean energy sources, amounts to 12.7 cents per kilowatt/hour for the first 500 kilowatts of the rated average annual capacity; 8.3 cents per kilowatt/hour for the rated average annual capacity between 500 kilowatts and 2 megawatts etc. and finally goes down to 3.4 cent for a capacity over 50 MW. The current Feed-in Tariff system includes a decrease of the tariff for hydropower by 1% per year, starting in 2013.

In 2013, the Ministry for the Environment was still in charge of funding research on renewable energies, including wave and tidal technologies. Details of the currently funded projects can be found in the 2012 country report. In addition, the Ministry of Economics and Technology runs the research programme "Next generation maritime technologies", which is valid for the period 2011-2015 and covers shipbuilding, navigation and maritime technologies. Marine energy technologies are explicitly mentioned under the strategic objectives for maritime technologies due to the significant future opportunities these offer. Consequently, R&D projects with regard to ocean energy technologies are in principle eligible under this programme.

PUBLIC AND PRIVATE R&D

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 was approximately €160 million in 2011. This programme is open to ocean energy research. Up to now, six technology projects related to the development of components and concepts for tidal turbines and wave energy components have been

funded by the federal Environment Ministry (BMU) with a total amount of around €7 million. For details please see the 2012 country report for Germany.

Former Siemens subsidiary, Marine Current Turbines (MCT), responsible for the yearlong successful operation of the 1.2 MW SeaGen S device at Strangford Lough, Northern Ireland, was sold to Singapore based Atlantis Resources Limited in mid - 2015 after being acquired by Siemens in 2012.
Voith Hydro Ocean Current Technologies, former joint venture of Voith Hydro and Innogy Venture Capital and being behind the testing of the HyTide 1000-16 tidal turbine demonstrator at EMEC in 2013 and 2014, have terminated these activities.

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. 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 Project "Development and Optimization of a Drive Train for Tidal Current Turbines" by ANDRITZ HYDRO was successfully finished in 2015 after running for more than two and a half years. Details of the project outcome have not been published yet.

The EpoSil (Electro-Active Polymers Based on Silicon for Power Generation) project, conducted by Robert Bosch GmbH, Bosch Rexroth, Wacker Chemie AG, Brinkmeyer & Partner, Technical University of Darmstadt and Technical University of Hamburg-Harburg, ended in early 2015. Its aim was to research electro-active polymers for wave power and potentially other applications. An appropriate polymer and a small scale point absorber demonstrator have been developed in the course of the project and being researched at the Hamburg test basin.

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, a floating service platform was prepared at the port of Hanstholm, waiting for tow-out in 2016 to be utilized for anchor drag tests and installation works (source: www.nemos.org).

Wave power developer SINN Power GmbH announced in late 2015 that their first wave power module has been successfully installed on the Island of Crete, Greece, and has generated power from ocean waves (source: www.sinnpower.com).

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

IRELAND

DECLAN MEALLY *Sustainable Energy Authority of Ireland*

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 2015. 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 overarching 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 before the end of 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.

Ocean Energy Portal

The Ocean Energy Portal was launched in November 2014, and has been significantly updated and enhanced throughout 2015. The portal acts as a 'sign-post' to guide interested parties, internal and from abroad, 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. Since its launch, the Portal has become the "first stop shop" to which all developers can engage with relevant support sectors in Ireland and from where they can obtain the most relevant and up to date information (www.oceanenergyireland.ie)

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 30MW for ocean (wave and tidal), focusing on pre-commercial trials and demonstration.

In July 2016, DCENR published a Technology Review Consultation, the first stage in a review of renewable electricity support schemes. 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 2016 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 (SEAI) 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. Sixty five technology projects have received support from SEAI since the programme was launched in 2009.

Fifteen new projects were awarded grants totalling €4.3 million through the Prototype Development Fund in 2015. Successful applicants include Ocean Energy Ltd., who secured €2.3 million to design and build a full scale version of their OE Buoy wave energy converter which will be deployed and tested at the US Navy Wave Energy Test Site in Hawaii. Other examples include SeaPower, who will receive over €1 million to test their wave energy converter at quarter scale in Galway Bay, while GKinetic Energy were awarded almost €200,000 to conduct towing tests of their tidal turbine system in Limerick Docks. Other projects include physical tank testing of early stage wave energy convertor concepts and feasibility studies of potential deployment sites.

OCEANERA-NET

The ERA-NET scheme is an innovative component of the European Union's Framework Programme, which supports cooperation of national/regional research funding programmes to strengthen the European Research Area (ERA). 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.

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 2015.

Galway Bay Ocean 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 1.5km offshore in water depths ranging from 20m – 23m. The site has provided test and validation facilities for a number of wave energy devices and components to date.

2015 saw the installation of a 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.
Separately, SEAI announced a Memorandum of Understanding with Apple in November 2015 to promote the development of ocean energy in Ireland. Apple has committed a €1 million fund that will help developers who receive a SEAI grant to test their ocean energy prototypes in the Galway Bay Ocean Energy Test Site.

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, and it is expected that planning permission for the onshore aspects of the site, including the electrical substation, will be submitted early 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.

RESEARCH & DEVELOPMENT

GOVERNMENT FUNDED R&D

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 2015, MaREI had approximately 90 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 small and medium enterprises across the marine and renewable energy spaces, to the value of €5 million.

Beaufort Building and Lir NOTF

Housing the headquarters of MaREI, the new Beaufort Building at Ringaskiddy, Cork, was officially opened by Taoiseach Enda Kenny during July 2015, representing a major extension of UCC's Environmental Research Institute (ERI). The Building covers some 4700m^2 on five floors and has provision for 135 researchers and support staff in offices and across a suite of state-of-the-art test tanks and dedicated workshops. It also includes Lir-NOTF, Ireland's National Ocean Test Facility, comprising a 2,600m^2 tank-hall, which will house 4 different wave tanks and a suite of electrical test infrastructure.

MaREI also secured over €4 million in additional funding from the SFI Infrastructure Fund in late 2015, which will allow the addition of an 'Open Ocean Emulator' at Lir-NOTF to accurately replicate real ocean wave conditions, and the development of an MRE Remotely Operated Vehicle by Prof. Dan Toal to address issues experienced by conventional equipment in challenging high-energy offshore conditions.

PARTICIPATION IN COLLABORATIVE INTERNATIONAL PROJECTS

Ocean Energy Forum – The Ocean Energy Forum has been created by the European Commission DG MARE to bring together stakeholders to develop a shared understanding of the problems faced by the Ocean Energy sector and to collectively devise workable solutions. Irish representatives have been active in developing the draft Strategic Roadmap which sets out the industry's six-point plan for bringing ocean energy technologies to the marketplace.

The European Commissioner for Fisheries and Maritime Affairs, Karmenu Vella, convened a high level session of the Ocean Energy Forum in Dublin in October 2015 to discuss the first conclusions of the draft Strategic Roadmap. This event was attended by several ministers from participating member states, including Ireland's Minister for Communications Energy and Natural Resources Alex White.

The Ocean Energy Forum event was held to coincide with the annual Ocean Energy Europe Conference & Exhibition which took place in Croke Park Dublin and was sponsored by SEAI.

IEC TC114 - Ireland has a mirror committee (TC18) and contributes with experts to the International Electrotechnical Commission's TC114 in the development of standards and guidelines for the ocean energy industry. Ireland has expert participation in the majority of the Work Programme. The TC114 International Plenary Meeting and related PT Meetings were held in Dublin Castle in April 2015.

Competition on Hydrodynamic Modelling of a Rigid Body - Launched by Prof. John Ringwood and Prof. Frederic Dias of MaREI, this competition sought to evaluate different ways to model and simulate a device. Six teams from Korea, Canada, USA, Ireland and Norway submitted entries to the competition, which was won by a team from NREL in the USA. The results were presented at two special sessions of the ASME 34th International Conference on Offshore Mechanics and Artic Engineering in Canada in June.

International Smart Ocean Graduate Education Initiative - Ireland has a graduate programme co-funded by members of the SmartOcean group, which has a mix of Irish and International entities. The first round of PhDs started in 2013.

EU PROJECTS

To date, MaREI has secured a total of over €6 million in EU funding, and has implemented academic collaborations with 67 other institutions across 19 countries, resulting in 149 journal publications and 133 conference proceedings. Ocean energy projects that MaREI researchers are participating in include:

- **FloTEC *(Floating Tidal Energy Commercialisation project)*** - The FloTEC project will demonstrate the potential for floating tidal stream turbines to provide low cost, high value energy to the European grid mix. The project will entail the construction of a turbine device that will be deployed alongside an existing floating tidal array which will serve as a demonstration platform for commercially viable tidal stream energy. The FloTEC consortium brings together world leaders in tidal energy with partners that cover all parts of the supply chain, including end users.

- **INNOWAVE (*Maximising the technical and economic performance of real wave energy devices*)** - INNOWAVE's focus is on the wave energy sector and the project provides an innovative training programme that integrates academic and industrial contributions. The INNOWAVE programme comprises formal and informal training activities with a rich set of industry-academic research projects, which will provide access to real world tank and ocean testing, wave-energy device deployment and implementation of new research results in state-of-the-art wave energy technology.

- ***MARIBE (Maximising the technical and economic performance of real wave energy devices)*** - MARIBE aims to identify opportunities for Blue Growth sectors to combine with other sectors via multi-use of space or in multi-use platforms (MUPs) and assist in the development of the most promising projects within these combinations. The analysis undertaken by MARIBE partners of key technical and non-technical challenges facing offshore projects will help determine how well placed offshore projects are to progress to pilot and commercial levels. MARIBE partners also incorporate input from the project's extensive stakeholder network to inform the project approach and activities.

- ***OPERA (Open Sea Operating Experience to Reduce Wave Energy Cost)*** - The primary objective of OPERA is to gather open sea operating experience to reduce the cost of wave energy. A key challenge to realising the potential of Europe's wave energy resource relates to data access; the wave energy R&D community does not always have access to open sea operating test data. OPERA will remove this roadblock by collecting and sharing two years of open sea operating data of a floating oscillating water column wave energy converter. Documenting and sharing this open sea experience will induce a step change in terms of knowledge of risk and uncertainties, costs and societal and environmental impacts of wave energy.

- **RICORE (*Risk Based Consenting of Offshore Renewable Energy Projects*)** - Consenting of offshore renewable energy is often cited as a critical non-technical barrier to the development of the sector. The RICORE project aims to establish a risk based approach to the consenting process for offshore renewables. Current legal frameworks as well as practices, methodologies and implementation of pre consent surveys, post consent and post deployment monitoring are examined with a view to developing best practices for overcoming barriers and ensuring compliance. RICORE partners work with relevant stakeholders including regulators, industry and EIA practitioners, through a series of expert workshops and use this engagement to guide the project's activities.

TECHNOLOGY DEMONSTRATION

OPERATIONAL PROJECTS

Technology from Ideas (TfI) - Technology from Ideas successfully installed and tested their elastomeric mooring tethers on a Mobilis 8000 data buoy at the Galway Bay Quarter Scale Test Site, building on previous trials at the site. The TfI system is designed to substantially reduce the loads experienced by floating devices during extreme weather events. The tethers consist of a soft elastomeric rubber component which stretches in normal sea states and stiffer thermoplastic spring components, which compress at the higher storm loads. The project demonstrated that the springs engage as expected and that the polymer mooring tethers can protect the data buoy as designed from 100 year storm scenarios.

GKinetic - 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 of towing tests of a 1/10 scale version of the turbine system in Limerick Docks in late 2015 in order to understand and assess the performance of the technology.

WestWave – 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 securing the required permits, conducting site investigations, including detailed wave measurements, and 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 2016.

ITALY

LUCA BENEDETTI *Gestore dei Servizi Energetici (GSE)*

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 been recently recognized by 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 groundbreaking 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. R

REGULATORY FRAMEWORK

The Ministerial Decree on renewable energy sources (DM 6 July 2012) reviews the support schemes (until the end of 2012 based on Feed-in Tariffs and Green Certificates) for grid connected renewable energy power plants (non PV). The Decree concerns plants put into operation since 1 January 2013 (with capacity ≥ 1 kW).

The Decree identifies four different ways of access to incentives: direct access, bid auctions (Dutch Auctions), registries for new power plants, for fully reconstructed power plants, for reactivated, empowered and hybrid power plants and registries for rebuilding intervention. The Decree defines the criteria to access 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 > 1 MW can only receive the incentive (fixed tariff minus electricity hourly zonal price, plus premiums if foreseen). Power plants with a capacity ≤ 1 MW 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 30% 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	
	≥ 1 kW and ≤ 60 kW	> 60 kW and ≤ 5 MW
Wave and tidal power plants	Direct Access*	Registry

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

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 indicated in the table below:

	2013	2014	2015
Wave and tidal power plants	3	0	0

If the total installed capacity in a certain year is less than the capacity to be supported in that year according to the Decree, the residual capacity can obtain the incentives in the following year. In 2012 and in 2013, there were not requests to enrol to the register, while in 2014 a single initiative, with capacity of 99 kW, was admitted to the register.

The wave and tidal energy rebuilt power plants can only access directly to incentives and their capacity must not be higher than 60 kW. The Decree does not provide Dutch Auction for wave and tidal energy power plants.

SOURCE	TYPOLOGY	CAPACITY (kW)	CONVENTIONAL PLANT'S LIFE (YEARS)	FIXED TARIFF/MWh
Oceanic (tides and waves)		1< P ≤ 5000	15	300
		P > 5000	20	194

In general, the tariffs for plants entering into operation from 2014 on will decrease by 2% (compared to the values provided by the Decree) in each of the subsequent years until 2015, except in case of failure to reach 80% of the yearly capacity quota provided for the register. In the case of wave and tidal energy power plants, the above mentioned curtailment will not apply because the total capacity provided by the Decree is still fully available.

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. Among these, the University of Naples "Federico II" is distinguished for its GEM project started in 2003. In fact, the public/private consortium SEAPOWER Scarl (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 - Aerospace Division, University of Naples "Federico II" and Eng. Nicola Giorgio Morrone, developed one of the most attractive project 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 opened to Italian and to foreign companies for testing their tidal current devices in the Strait of Messina . 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.
In the field of wave energy, SEAPOWER has also started a cooperation with Umbra Group (www.umbragroup.it), world leader company in ball screws and linear actuators, to develop a system aimed to harvest energy from wave motion. The system has been designed keeping it as simple as possible with reliability and survivability as main driving criteria. Numerical and experimental tests on 1:5 scaled model have already been performed in the towing tank of the Department of Industrial Engineering of the University of Naples "Federico II".
Set up and validation of numerical codes have already been done as well as shape optimization procedure in order to maximize the power output given the sea state. A 60 kW prototype is being designed to be deployed on the Italian coast in order to verify its performance in real field.

R&D PROJECTS

A list of the projects that Politecnico di Torino (POLITO) managed/currently manages along with a brief description regarding the objectives of each project is given below:

▸ National project "Evaluation of Effective Productivity of Floating System for Energy Generation from Mediterranean Saw Wave" (2011-2012).
In the frame of the Italian national agreement between ENEA and the Ministry of Economic Development on the National Energy Research Set Plan, a special contract was signed (2011-2012).
The partnership is formed by POLITO and ENEA aiming at the evaluation of the effective productivity of floating system for sea wave energy conversion.
In particular, the following actions will be pursued:
- Wave analysis in Pantelleria with numerical methods;
- Productivity estimation of a gyroscopic converter device and possible integration in the power grid.

▸ Regional project S.PO.S.DE.T. "Self Powered Floating Device for Sea Traffic Detection and Transmission" - Regione Piemonte (2009-2011)
In the frame of the regional research plan (Regione Piemonte), a project was financed regarding the development of ISWEC, an innovative device (scale 1:8 with respect to the Pantelleria typical wave) for energy generation and sea wave energy conversion. The complex system is currently under testing at the Pantelleria premises and further development is foreseen.

▸ Regional project PROMO - Produzione di Energia da Moto Ondoso - Regione Piemonte (2012-2014)
In the frame of regional research plan (Regione Piemonte) Politecnico di Torino has received a grant for design, development and testing of a full scale device for sea wave energy conversion. Politecnico di Torino, in cooperation with Wave for Energy, is currently working for the device integration on the energy power grid, in order to evaluate the quality of energy produced from renewable sources.

▸ Regional project REMOTO - Produzione di Energia da Moto Ondoso - Regione Siciliana (2013-2015) In the frame of regional research plan (Regione Sicilia), Wave for Energy and other partners have received a grant for deployment and grid connection of a full scale device for sea wave energy conversion.

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 – Naval Division 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 be 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 m2). 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.

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.

Full scale ISWEC drawing (CAD) with two gyros

The conversion device to be built will have the following features:

- floating positioning system, with no need for rigid linking devices or foundations on the seabed;

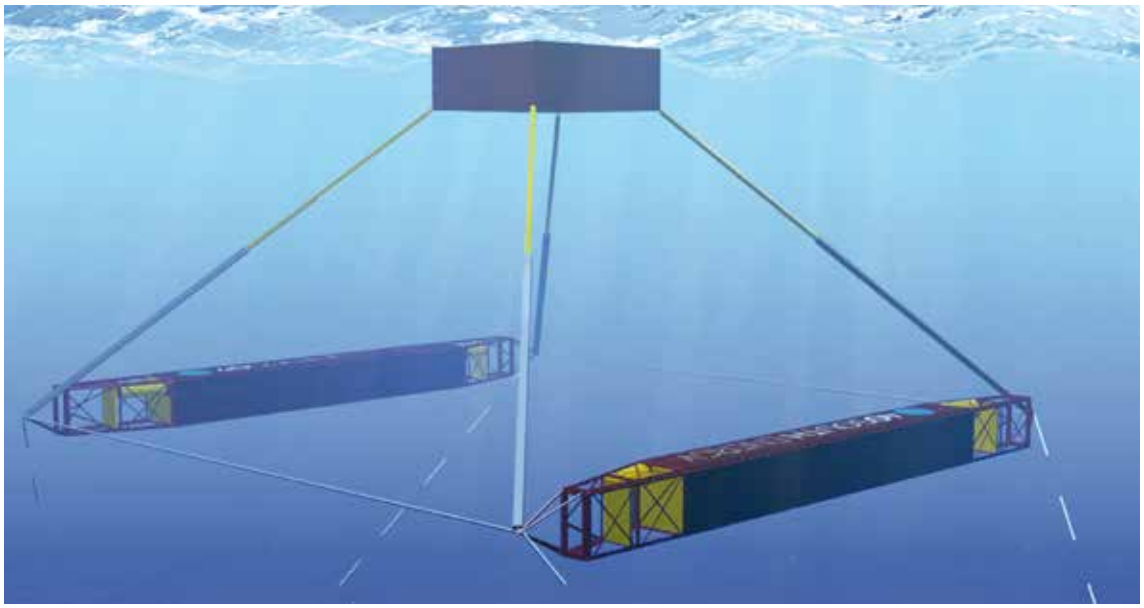
functioning is based on a resonant inertial system with gyroscopic;

- sealed hull, with no movable parts exposed to marine environment;
- adaptability to wave variations;
- reduced environmental impact;
- ease of maintenance.

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.
Currently the real scale prototype is under development and it is going to be launched.

PLANNED DEPLOYMENTS

Last june, Enel Green Power, a world leader in renewable energy generation, and 40South Energy, a group of highly innovative companies operating in the field of marine energy at the international level, began the installation and commissioning of a first R115 generator, with a nominal capacity of 150 kW and installed capacity of about 100 kW, generating electricity from the energy produced by the waves of the sea around Tuscany. The 40South Energy wave energy converters comprise one fully submerged section – called Lower Member – and energy interceptors – called Upper Members – at different depths. The relative motion of the Lower and Upper members is converted directly into electricity on the machine. The depth of the machines is controlled automatically to respond dynamically to changing sea conditions. This ability to vary depth dynamically and automatically in response to any changes in the state of the sea also guarantees that the same machines can operate across the globe. Whether the installation is in Orkney, Tuscany, or Oregon, the machine will work within the same operational limits.



The new generator ensures full integration into the marine environment and ease of maintenance, and according to initial estimates will enable the generation of about 220 MWh per year, enough to meet the needs of over 80 households.
40South Energy has handled the installation and commissioning of the machine, which began to produce the first electricity. Partners will continue assessing the performance of the system in the marine environment during 2015 in light of installing the machine and connecting to the network on the Elba Island during second half of the year.
40South Energy, in its continuous efforts to strive for utilizing the marine energy resources, is also developing a 50 kW solution to install near shore and depth of 8 m within 200 m from the costal line.

OTHER RELEVANT NATIONAL ACTIVITIES

FP7-ENERGY-2012: SINGULAR: 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.

MEXICO

CARLOS ORTIZ GOMEZ *Secretary of Energy (SENER)*

SUPPORTING POLICIES FOR OCEAN ENERGY

Mexico has experimented relevant policy changes during this year lined up with its interest in building a sustainable future. The most important of these changes is the Energy Reform which was approved by the Congress in December 2013 and whose legal framework was promulgated on 11 August 2014. These new laws have fully opened the power sector to a free electricity market by letting private companies participate in the generation, transmission and distribution stages, making the energy industry more competitive, efficient and inclusive.

The Energy Reform also emphasizes a major inclusion of renewable energies in the electricity generation. Prove of this is the recently published Law of Geothermal Energy, and the Law of Electrical Industry which replaces the old Law of the Public Service of Electrical Energy and lays the foundations for a more sustainable industry through the acquisition of Clean Energy Certificates.

Therefore, the country has been building the accurate environment for a complete sustainable energy transition in which clean technologies like those of ocean energy will be crucial for achieving such an ambitious goal.

NATIONAL STRATEGY

Although Mexico has not a specific national strategy for developing ocean energy, it has several dispositions for developing renewable energies as part of a green energy policy integrated by the National Strategy of Energy 2013-2027, which is a legal instrument that sets out the challenges for the energy sector and establishes the further actions to address them; the National Strategy for Energy Transition and Sustainable Use of Energy 2013, which is the mechanism that encourages and promotes the use of non-fossil energy sources; the Use of Renewable Energies Special Programme 2014-2018 and the Climate Change Special Programme 2014-2018.

The 10th Strategic Topic of the first governmental mechanisms mentioned before stresses the need of diversifying the energetic matrix with the purpose of reaching the 35% of the total electrical generation by 2024 with clean energy sources; a national goal that has been established in the Law of the Use of Renewable Energies and Energy Transition Funding since its promulgation in 2008 by determining a maximum participation of fossil fuels of the 65% and reinforced in the 3rd transitional article of the General Law of Climate Change promulgated in 2012.

Likewise, the other documents set out the targets, guidelines and actions to boost and optimize the Mexican energy sector by disseminating the advantages of clean energy sources and encouraging public and private projects with the objective of developing a clean technology, in order to harness these resources and contribute to the Nation's sustainable development.

REGULATORY FRAMEWORK

There is not a specific regulation for ocean energy currently in Mexico. However, there is a law applicable to all renewable energies, the Law of Energy Transition.
This law regulates the renewable energies and clean technologies harnessing to generate electricity with private purposes. Likewise, it establishes the national strategy for energy transition funding.

MARKET INCENTIVES

The new regulation that was promulgated on 11 August 2014 as a result of the Energy Reform has set up a new incentive called Clean Energy Certificates (CELs).

These certificates will be granted by the Energy Regulatory Commission (CRE) and will be given to those producers that generate electricity from clean energy sources. The owners of the certificates will be able to negotiate and commercialize them as a commodity in order to potentiate its benefits. Since this is a new initiative, the operation rules have not been established, however this regulation is expected to be promulgated during the first three months of next year.

The Clean Energy Certificates were lay down by the Mexican Government as a mechanism of control and promotion of the renewables industry growth. Therefore, ocean energy developers will be suitable candidates to receive CELs because of the great potential of the Mexican territory that can be harnessed and the particular advantages of this resource.

PUBLIC FUNDING PROGRAMMES

There are three major funding sources in Mexico created to support and promote the development of renewable energies and energy efficiency projects carried on by higher education institutions, research centres and private companies with technological basis in order to encourage interesting synergies between the academy and the industry for the Nation's development and economic growth.

Energy Sustainability Fund (Fondo Sectorial Conacyt-Secretaría de Energía-Sustentabilidad Energética)

Authority: Secretariat of Energy (SENER) and National Council of Science and Technology (CONACYT)

Programme: There are several programmes with different purposes derived from this fund. The most significant are:

- Institutional Strengthening for Energy Sustainability.
- Mexican Innovation Centre in Ocean Energy (CEMIE Océano).

This fund was created to solve the main problem areas of the energy sector and to boost the scientific research as well as the technological development of energy sustainability. Therefore, it offers public mechanisms to encourage the academia and the industry to present proposals whose objectives match with the purpose of the fund. In this sense, in September 2014, the CONACYT and SENER made a call to research centres, higher education institutions and private companies interested in developing ocean energy technologies to integrate a consortium and form the Mexican Innovation Centre in Ocean Energy (CEMIE Oceano).

Fund: Energy Transition and its Sustainable Use Fund (Fondo para la Transición Energética y el Aprovechamiento Sustentable de la Energía FOTEASE)

Authority: Secretariat of Energy (SENER)

Program: There are not public calls to present proposals. The technical committee of the fund is the one who decides how to distribute the financial resources. This fund was created because of the 27th article of the Law of the Use of Renewable Energies and Energy Transition Funding with the purpose of financing integral projects that impact the energy sector and promote continuous income to renew the financial resources established for the fund. The recent Law of Energy Transition also includes the usage of the different energy sector funds to support and promote the development of clean energies.

Permitting and Licensing Process for ocean energy projects

To complement the regulatory framework to the granting of permits for projects that harness ocean energy to generate power, in October 2015 a study started with the aim to provide the basis for the projects that are being tested can access a permit and can generate energy; the study is expected to be completed in March 2016.

RESEARCH & DEVELOPMENT

KEY R&D INSTITUTIONS AND RELEVANT R&D PROJECTS

The Mexican Innovation Centre for Ocean Energy (CEMIE Oceano) was officially launched in December 2015, and will focus on the development of technological roadmaps, and on the definition of priority topics for scientific research and ocean energy technologies within the country, as well as the training and specialization of human resources and joining the efforts from academia and industry. The resources will be granted for up to 348 million pesos, over a period of four years. Together, the Sustainable Energy Fund, institutions and participating companies will contribute with a total investment of 374 million pesos.

In the first year, the Advisory Council of CEMIE Ocean will be coordinated by the Institute of Engineering of the National Autonomous University of Mexico (UNAM) and will involve 50 institutions and four companies comprising the consortium.

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 the OES in June 2013. This action was part of the Government concerns for combating climate change and recognizing the relevance for 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.

ENERGY POLICIES

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, a dedicated funding instrument has 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.
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, the Association Monegasque pour la Protection de la Nature.

PERMITTING AND LICENSING 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.

TEST SITES

Monaco wishes to develop ocean energy. Currently, sea water heat pumps produce a significant share of the Principality's energy needs.

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.

A buoy was installed in partnership with the National Centre for Archiving Swell Measurements. It measures 4 types of data:

- Height of the waves;
- Their direction;
- Their frequency;
- Temperature of the water surface.
- Live data on the website: http://candhis.cetmef.developpement-durable.gouv.fr/

TECHNOLOGY DEMONSTRATION

OPERATIONAL PROJECTS

In Monaco, the sea is used as a renewable energy source for the development of a heat pump system. The first heat pump with sea water in Monaco dates back to 1963.
In 2015, 70 heat pumps produced 17% of the energy consumed in the Principality (about 176 602 MWh/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 of 15,000 metric tons of oil per year.

PLANNED DEPLOYMENTS

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

OTHER RELEVANT NATIONAL ACTIVITIES

March 31st until April 2nd 2015 - EVER Monaco (Ecologic Vehicles/renewable Energies): A roundtable was dedicated to the "State of play and potential and development of Marine Energies", in the presence of Mrs Ana Brito Melo, as Executive Secretary of the OES.

NETHERLANDS

JOS REIJNDERS *Netherlands Enterprise Agency (RVO)*

INTRODUCTORY NOTE

On 10 September 2014, the Netherlands officially became a party to the OES with the Netherlands Enterprise Agency (RVO.nl) as Contracting Party.

In the Netherlands, both the Government and commercial parties have been studying the potential of ocean energy since the 1980s. Business and other organizations have joined forces in a trade association called the EWA (Netherlands Energy from Water Agency). Pilots have been carried out in Dutch waters to test various ocean energy technologies.

In the second half of 2014, the Ministry of Economic Affairs and the Ministry of Infrastructure and the Environment commissioned a study into the export potential of Dutch companies involved with energy from water (short term potential; up until 2023), and the potential contribution this technology could make to the Netherlands' energy transition over the long term (2035). The results formed the basis for talks on potential follow-up activities between the above mentioned ministries and the sector.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

Currently, 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.

A spatial analysis of the potential of the North Sea with a view to 2050 has been made, also with regard to ocean energy. The North Sea Spatial Agenda was sent to the parliament on 28 July 2014 and 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 cm/sec. A further study was commissioned by the Ministries of Economical Affairs and Infrastructure and the Environment in 2014; that is to form the foundation for a targeted governmental vision on ocean energy. A separate study was commissioned by the working group on Offshore Wind to investigate the needs of the Dutch tidal and wave energy sector.

REGULATORY FRAMEWORK

Although there is a central permitting system, in practice consenting requires engagement with a wide range of permitting bodies, such as the Central Government, province, municipality, Rijkswaterstaat, local harbour authorities, Ministry of Defence and the regional water board. There are currently no specific aspects relating to ocean energy that are the focus of new or improved legislation or regulations.

MARKET INCENTIVES

There are currently no specific market incentives for ocean energy. The Netherlands promotes use of space at sea from a perspective of inviting for developments. The generic DEI (Demonstration of Energy innovations) subsidy scheme supports projects with a focus on export of Dutch technology.

PUBLIC FUNDING PROGRAMMES

Since the 1990s the Ministry of Economical 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 in the DEI (Demonstration of Energy innovations) subsidy scheme; BlueTec and Tocardo-Huisman.

MARINE SPATIAL PLANNING POLICY

The marine spatial planning is focused on offshore wind, special areas have been appointed for offshore wind. There are no offshore ocean energy projects planned yet. In the future, cooperation with the existing offshore spatial planning is foreseen. All existing ocean energy demonstration projects are located close to the shore line and close to or in barriers, this does not affect existing marine spatial plans.

PERMITTING AND LICENSING PROCESS FOR OCEAN ENERGY PROJECTS

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.

TEST SITES

- Den Oever – Tocardo; tidal currents up to 5 m/sec.
- Grevelingen Barrier; low head tidal test centrum (planned)
- Labschale test sites; Marin, TU Delft, Deltares, TNO, Wetsus, Imares, ECN

RESEARCH & DEVELOPMENT

- Tocardo Den Oever; tidal current, free flow
- BlueWater Delft; tidal energy, free flow
- REDstack Sneek; salinity gradient energy
- Bluerise Delft; OTEC
- Teamwork Technology; wave energy (Archimedes Wave Swing)
- Tocardo VAWT; tidal current, Vertical Axis Wave Rotor Technology

TECHNOLOGY DEMONSTRATION

OPERATIONAL PROJECTS

Bluewater floating 100 kW tidal energy

Tocardo-Huisman 1,2 MW tidal energy

PLANNED DEPLOYMENTS

- OTEC Pilot Curacao (500 kW)
- 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 scenario's)
- Several arrays in Afsluitdijk discharge gates (further future)

OTHER RELEVANT NATIONAL ACTIVITIES

EIP Water Conference & Site Visit Leeuwarden on 9, 10, 11 February

NEW ZEALAND

CRAIG STEVENS *AWATEA/NIWA/Univ. Auckland*

INTRODUCTORY NOTE

With a population of 4.4 million people and the world's 5th largest Exclusive Economic Zone (EEZ), 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. With a significant EEZ, one of the world's largest, there are opportunities to become a "marine society" (Stevens & O'Callaghan, NZ Journal of the Royal Society, 2015, DOI:10.1080/03036758.2015.1014377).

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. Two recent landmark cases 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 project funded by the investigator-led Marsden Fund on large array scaling and design (PI Ross Vennell, Univ. Otago) is nearing completion.

SEA TEST SITES

NZ-MEC is a proposed R&D and test site off the Wellington coast. The establishment of NZ-MEC will be a catalyst to launching New Zealand's marine energy supply chain into the fast growing global marine energy fabrication and servicing industry, creating prototypes and eventually export-oriented commercial device production opportunities for New Zealand companies. NZ-MEC will play a key facilitation role, connecting its device developer clients and their service needs with local marine energy supply chain participants such as design engineering firms, fabricators, offshore services and equipment suppliers. Identifying and exploiting niche opportunities by NZ-MEC and New Zealand's marine energy supply chain will be key to achieving this outcome. It presently sits as a business case before the MBIE (Ministry for Business, Innovation and Employment). The potential for a go-ahead lies with the possibility of an overseas technology developer trialling a new device.

RESEARCH & DEVELOPMENT

KEY R&D INSTITUTIONS AND RELEVANT R&D PROJECTS

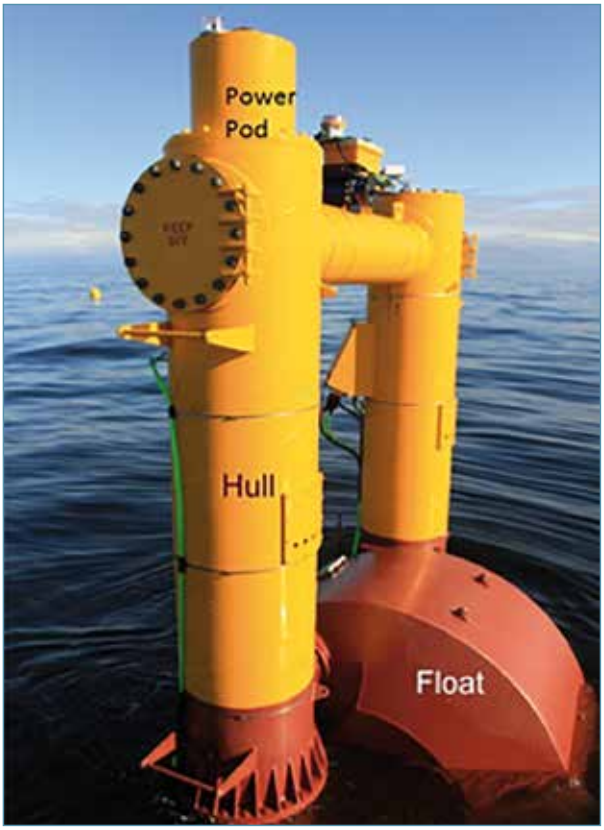
- NIWA – National Institute for Water and Atmospheric Research – Government-owned environmental research agency with a focus on atmospheric and aquatic environments that operates ocean-going vessels (www.niwa.co.nz).
- HERA – Heavy Engineering Research Association (http://www.hera.org.nz/MainMenu)
- 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) which focuses on vocational education with special relevance of design and engineering courses.
- AUT (www.aut.ac.nz/study-at-aut/study-areas/engineering/undergraduate/maritime-majors)
- Callaghan Innovation (http://www.callaghaninnovation.govt.nz/)

TECHNOLOGY DEMONSTRATION

The big story in the technology space was the success of AzuraWave. 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 deployed as a grid connected demonstration project at the US Navy's wave energy test site at the Marine Corps Base in Hawai'i.

Unlike other wave energy technologies, AzuraWave 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.



AZURAWAVE (http://azurawave.com)

OTHER RELEVANT NATIONAL ACTIVITIES

AWATEA – Aotearoa (New Zealand) Wave and Tidal Energy Association

www.awatea.org.nz

Is relatively active for the size of the local industry. 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;
- Promote exchange for 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, nongovernmental organizations and other industry bodies and liaise with other international bodies.

AWATEA produced a white paper in early 2014 laying out some ideas for future development. (http://www.awatea.org.nz/information/white-paper/). It also runs a well-attended annual conference. The focus of the 2015 conference was around new tidal technology, the AzuraWave project and the demand side implications of a growing electric vehicle fleet. The conference also introduced a range of short projects using the Pecha Kuchatalk format (http://www.pechakucha.org/) which proved to be a useful way of presenting technical material to a broad audience. The chair of the association shifted from NIWA to WelTec in 2015, reflecting a shift in interest towards the educational sector in an effort to build groundswell for the industry.

Sustainable Seas – a new government funding initiative

www.sustainableseaschallenge.co.nz/

The aim of the Sustainable Seas National Science Challenge is 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. This spent most of 2015 in planning and work will commence in 2016. It is not clear that there will be support for MRE until the present focus on marine ecology evolves.

NORWAY

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

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.

MARKET INCENTIVES

In 2011, Norway and Sweden signed an agreement for a joint green certificate market. One certificate per MWh would, from 2012, be given to all new renewable energy generation in 15 years, independent of technology.
The price per certificate is driven by the market with a common target of 26.4 TWh by the end of 2020. The total compensation (el-spot + certificate) for the renewable producers is in the long term believed to be approximately €50-55/MWh. A total income in this range is almost certainly not enough for wave and tidal projects in the next decade. Instead, the governmental support programmes for research and development are intended to drive the development.

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. For 2014, these three institutions had a combined budget of approximately €110 million.

MARINE SPATIAL PLANNING POLICY

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 on 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.

PERMITTING AND LICENSING PROCESS FOR OCEAN ENERGY PROJECTS

The licensing body NVE continues to prioritize small scale demonstration projects located near shore according to the existing Ocean Energy Bill. The licensing process is efficient and pragmatic since the demonstration projects are small in physical installations and operation time.

TEST SITES

Runde Environmental Centre (REC), located on Runde Island on the Norwegian west coast, can accommodate WEC plants for test and demonstration at several sites. One has a 3 km/0.5 MW sea cable to shore with grid connection. REC facilitates preparations, licensing, deployment and monitoring of the WECs, and works also on other forms of ocean energy, building national competence and capacity. The next WEC developer to deploy is Waves4power. Planning for a facility for testing of tidal energy devices at Brevik (Drammen) is in progress, in cooperation with REC.

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.

RESEARCH & DEVELOPMENT

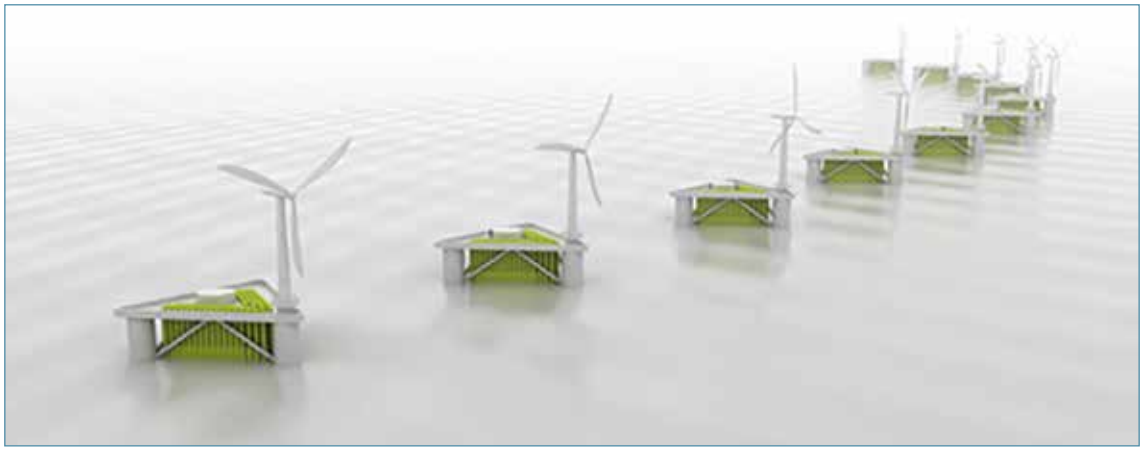
The research cluster in Trondheim, comprising NTNU and SINTEF/MARINTEK, is active in ocean energy research. Some of the activities are: technology screening and verification, control systems, mooring, marine structures, safety, optimal design of devices and load modelling. MARINTEK's model tank is also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

TECHNOLOGY DEMONSTRATION

OPERATIONAL PROJECTS

Havkraft AS

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 Dr. Karl Christian Strømsem, Edgar Kvernevik, Agnar Lyng, Roger Fløtlo and a range of highly skilled partners, including Stadyard, Kvernevik Engineering, SmartMotor, Marintek Sintef, Christian Michelsen Research, Ulvesund Elektro and more.



PLANNED DEPLOYMENTS

Deep River

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 is under river and tidal testing during 2015 and 2016. The Deep River concept is turbine and generator on standard, container or pallet based solutions. Standardizing of 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 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.

Tidal Sails

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.

Tide Tec

TideTec is a Norwegian tidal company focused on developing the most efficient and flexible turbine technology for tidal barrage/lagoon and flood protection systems. TideTec holds several patents for state of the art tidal turbines and construction of tidal power plants. TideTec have patented a turnable turbine to be used in tidal-water power plants. The turbine enables efficient two-way production (ebb- and flood production) in tidal power plants. In addition the TideTec turbines can be used for both forward and reverse pumping which increases the power production and the flexibility of production. The technology is intended to be integrated to existing or planned transport infrastructure, such as road bridges.

Ocean Energy

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 the leading environments at universities in Norway (NTNU), as well as the "Maritime Cluster" at Ulsteinvik, Sunnmøre in western Norway (www.ocean-energy.no). The project is supported by Innovation Norway and Ocean Energy plans to install a demonstration at Runde.

Flumill

The company 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.

Langlee Wave Power

The wave energy converter, named Langlee Robusto is a semi-submerged, floating steel structure anchored to the seabed with four chains. Wave energy is captured by large water wings that swing back and forth with the waves, converting the energy into electricity by generators with minimum loss. The electricity is connected to the onshore grid by a subsea cable.

Andritz Hydro Hammerfest

The company was founded in Norway in 1997 by the local utility company Hammerfest Energy and is currently owned by Andritz Hydro, Iberdrola and Hammerfest Energi. Andritz Hydro Hammerfest is among the leading tidal energy technology developers in the world and is now taking the step into commercial delivery. The Company has unrivalled commercial operation experience and has received Carbon Trust funding for the tidal turbine development. In December 2012 Andritz Hydro Hammerfest was awarded €20,7 million from NER300 for the proposed Sound of Islay project. Andritz Hydro is also part of the Meygen tidal energy project.

PORTUGAL

ANA BRITO E MELO *WavEC*
ANTONIO FALCÃO *IST*

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The National Ocean Strategy (NOS) 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.

The NOS 2013-2020 presents a new development model of ocean and coastal areas to allow Portugal to meet the challenges for the promotion, growth and competitiveness of the maritime economy. It identifies the areas of intervention and presents an action plan, "Mar-Portugal Plan". One of the strategic actions is the support for new forms of technology applied to maritime activities, by creating conditions for the installation, testing and development of emerging forms of technology.

The maritime spatial planning system and the compatibility of the different existing and potential activities that may take place therein, along with the simplification of the respective administrative procedures, are key operations to the implementation of NOS 2013-2020.

Available at:
http://www.dgpm.mam.gov.pt/Documents/ENM_Final_EN_V2.pdf

REGULATORY FRAMEWORK

In March 2015, Law 38/2015 was published, implementing Law 17/2014, establishing the Policy on the National Maritime Areas Planning and Management (LBOGEM). LBOGEM defines the general principles applicable to maritime spatial planning and the legal framework relating to the use of Portugal's maritime areas.

The Resolution of the Council of Ministers no. 57/2015, of 30 July, approved the Financial Instrument for Energy, promoting the diversification and use of clean energy sources. The funds shall be partially conveyed by the allocation of European structural and investment funds for the period from 2014 to 2020.

The Ministerial Order no. 202/2015, of 13 July, approved the remuneration regime applicable for wave energy and offshore wind projects, at an experimental or pre-commercial stage. A basic Feed-In Tariff of €80/MWh is set for these projects, applicable to the first 20 years of the project. This value can be increased by €20/MWh if the projects have received incentives from the Portuguese Fund Carbon (FPC).

PUBLIC FUNDING PROGRAMMES

In Portugal, FCT (The Foundation for Science & Technology) is the main funding agency for research covering all fields of science, including ocean energy. 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. The first join call for proposals was launched in October 2014 and a number of projects were approved in 2015.

Agência Nacional de Inovação (ANI), which until September 2014 was known as AdI (Agência de Inovação), has also a role in funding applied research. It is managed together by

the two ministries (Ministry of Education Ministry of Science, Technology and Higher Education and the Ministry of Economy). Its main purpose is to stimulate business-oriented research in Portugal. The main source of the funds it manages comes from the Operational Programmes.

Portugal 2020, signed by Portugal and the European Commission, is the main instrument for business investment for the period 2014-2020, 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 these 2 topics can address marine energy technology:

- Competitiveness and internationalization through **COMPETE 2020** Programme;
- Sustainability and efficient use of resources through **PO SEUR** Programme.

On the Portugal 2020 website (www.portugal2020.pt) there is a Plan of Calls for Proposals, which enables future applicants to prepare and plan their projects. The Balcão 2020 site (https://balcao.portugal2020.pt) provides guidelines for submitting proposals.

MARINE SPATIAL PLANNING POLICY

In March 2015, the Portuguese Law 38/2015 was created laying down the bases for 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.

The approval and implementation of Portugal's legal regime on marine spatial planning and management of the national maritime space is a notable achievement for Portugal with respect to ocean governance.

PERMITTING AND LICENSING PROCESS FOR OCEAN ENERGY PROJECTS

- 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.

TEST SITES

In Portugal, a specific site for wave energy development – offshore S. Pedro de Moel, between Figueira da Foz and Nazaré - with an area of 320 km2, was designated by the Portuguese State, in 2008. It is a demarcated maritime space in water depths between 30 and 90 m. In 2010, ENONDAS (a subsidiary of the Portuguese Grid Transmission System Operator) received from the Portuguese State a public concession for this site for 45 years. Enondas has adopted the trading name of Ocean Plug. In 2015, there has not been much progress regarding the development of the infrastructure for the pilot zone.

RESEARCH & DEVELOPMENT

WAVEC OFFSHORE RENEWABLES

WavEC is a private non-profit association, currently with 13 associates (industrial and public), and devoted to the development and promotion of offshore energy utilization through 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.

In 2015, WavEC coordinated two European funded projects:

- **WETFEET**, initiated in June 2015, funded by the EU H2020, with 3 years duration. The overall objective is to understand and find solutions to the constraints of wave energy technology. In particular, the project seeks to identify the reasons that have been delaying the sector's progress and to propose viable solutions to improve the overall performance of new technologies.

It will address issues, such as reliability of technological components, survivability capacity of the devices, high development costs, long process for commercialization, as well as industrial scalability of tested technologies.

- **OCEANET** started in 2013 and will be concluded in 2016. It is a training network of young researchers in the area of floating offshore wind and wave energy (Funded by the EC 7th Framework Programme).

WavEC has been further collaborating with a number of European R&D consortiums, including:

- **RICORE** (2015 - 2016), dealing with consenting processes on marine renewable energy projects and aiming to establish a risk-based approach to consenting processes (funded by H2020).
- **DTOCEAN** (2013 - 2016), providing shared access design tools for wave and tidal energy converter arrays (funded by the EC 7th Framework Programme).
- P**olyWEC** (2012 - 2016), dealing with a new class of polymeric wave energy converters (PolyWECs), employing Electroactive Elastomer (EE) transducers (funded by the EC 7th Framework Programme).
- **HiWav**e (2013 - 2016) focused on the development of wave energy technology by the Swedish company Corpower, including tests at sea (funded by KIC InnoEnergy, a company funded by the EC European Institute of Technology (EIT), devoted to developing innovative industrial products).

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

INSTITUTO SUPERIOR TÉCNICO

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

- **Institute of Mechanical Engineering (IDMEC)** with a decades-long history in wave energy conversion studies;
- **Centre for Marine Technology and Engineering (CENTEC**) whose involvement in ocean energy is more recent.

Following previous years, the activity at IDMEC has concentrated on wave energy conversion, especially the development of new types of oscillating water column (OWC) converters and self-rectifying air turbines. Laboratory tests of moorings with imposed motion of the moored body have been performed to validate numerical codes. Small scale model tests of a patented new concept for a floating OWC have been performed at IST, in collaboration with LNEG, Lisbon. 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; this included numerical modelling and a hardware-in-the-loop testing at Tecnalia test rig (in Bilbao, Spain) within the framework of the FP7-MARINET programme. 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 self-rectifying air turbine, and the development of new concepts for floating OWCs. Modelling and optimization, combining CFD and model testing of the recently patented twin-rotor self-rectifying air turbine have been performed, in collaboration with the Universities of Valladolid and Oviedo (Spain). The results, published in the journal Energy, indicated a peak efficiency about 86%.

Ocean energy is becoming a major area in the diversified activity of CENTEC. The activities at CENTEC in ocean energy involved a wide range of topics covering waves, tidal currents and offshore wind. The characterization, in European waters (Iberian Peninsula, Galway Bay), of wave energy (and to a much lesser extent tidal and offshore wind energies) 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 PTOs (namely dual-chamber OWCs and hydraulic-circuit PTOs).

Since 2013, IST has been involved in the EUREC master course in Renewable Energy, offering a one-semester specialization in ocean energy. This took place in February to May 2015.

TECHNOLOGY DEMONSTRATION

OPERATIONAL PROJECTS

Pico Plant

On the Island of Pico, Azores, WavEC has been running, since 2004, an OWC wave energy pilot plant (www.pico-owc.net). This plant was built in 1995-1998 with support from the European Commission. Pico OWC is a unique structure, allowing testing commercially-sized air turbines and auxiliary systems (up to ~700kW), as well as research studies on fatigue/corrosion problems in a very rough (real) environment for the equipment. The plant is grid connected and has been permanently improved by WavEC with its own, minimal means. It has been providing operation data and training for young researchers.

WaveRoller

AW-Energy has built a full scale test facility; it is situated in a workshop in Finland. It consists of a full scale hydraulic power production machine "sea side" and a full scale hydraulic Power Take-Off (PTO). Real measured wave data is fed into the control system of the machine. The behaviour of the WaveRoller panel is simulated and the output of the simulations are mechanical movements and forces which move the real full scale PTO and create hydraulic power and finally the generator produces electric power. The produced electricity is fed via frequency converter to the grid of the workshop. The quality and amount of the produced electricity can be measured. The functioning of the PTO system can be improved with the help of this new test machinery.

AW-Energy is further developing the WaveRoller wave energy converter. In 2016, AW-Energy is going to deploy a new full scale grid connected WaveRoller in Peniche, Portugal. The year 2015 was used for the engineering work of this new device. AW-Energy has worked with a certification body, Lloyd's Register, which has given AW-Energy the Statement of Feasibility Certificate according to DNV RP-A203. The certification work continues towards type certification.

PLANNED DEPLOYMENTS

The Australian company, Bombora Wave Power, is planning its first real scale deployment to take place in Peniche. Feasibility studies have been initiated and during next year the company will apply for the licensing of a first experimental unit.

OTHER RELEVANT NATIONAL ACTIVITIES

The proceedings of the First International Conference on Renewable Energies Offshore, that took place in Lisbon in 2014 (organized by CENTEC), were published in mid-2015. The Second Conference will take place also at IST in 2016 (the deadline for abstract submissions was 30 December 2015).

WavEC Annual Seminar entitled **"Portugal and France - A driving force on research and innovation in Marine Renewable Energies"** was organized in Lisbon on 16-17 November 2015 with the collaboration of the French Embassy in Portugal, and invited speakers from France.

REPUBLIC OF KOREA

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

INTRODUCTORY NOTE

As the mid and long term plan for the clean ocean energy development was newly established with the purpose of enhancing the competitiveness in the world market, and stimulating the supply of ocean energy, the strategic plan was proposed. The objective of the strategic plan is strengthening the support policy and securing the infrastructure plan. Especially, as the tidal current power has been newly included in the REC, the supply is expected to be stimulated. The funding on the development of the renewable energy is increasing under the control of the Ministry of Oceans and Fisheries and the Ministry of Trade, Industry and Energy. In addition, the funding is focused on demonstration projects, and such projects are in progress, including the 300kW FPWEC, the 200kW ACHAT, and 200kW HOTEC.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The strategic plan for the "Mid-Term and Long-Term Clean Ocean Energy Development plan 2015-2025"has been recently established, which includes the national vision, long term goal, strategy, and an action plan for the new and renewable energy development for the period between 2015 and 2025. The strategy plan, which has been jointly developed by the MOF (Ministry of Oceans and Fisheries) and MOTIE (Ministry of Trade, Industry and Energy), was approved by the National Science and Technology Council in 2015.

The main objectives of the strategic plan are to set up a relevant R&D support programme, and to seek more efficient ways towards the ocean energy distribution. Meanwhile, the MOF updated the ocean energy R&D roadmap during 2015, where they planned to:

- Reinforce the infrastructures and accelerate the commercial development ;
- Organise the open sea testing facilities for wave and current devices;
- Collaborate with South Pacific Islands for the OTEC.

The initial target set before for the ocean energy distribution has significantly reduced down to 1.6% by 2025. Although the targeted distribution for the ocean energy was reduced, the second national energy master plan states that the overall targeted distribution for the new and renewable energy is increasing. It had been indicated that the ocean energy had difficulty of reaching its initial targeted value, due to stronger restrictions towards the environmental protection and reluctance of local residents.

REGULATORY FRAMEWORK

Although there is no explicit legislation or regulation related to the ocean energy itself, the action towards the development of the renewable energy by the nation is in progress, with documents such as the "Framework Act on Low Carbon, Green Growth", and the "Act on the Promotion of the Development, Use and Diffusion of New and Renewable Energy". In addition, there is the "Energy Act" for national acts on the energy and various regulatory measures for the marine environment protection, such as the "Framework Act on Marine Fishery Development" and the "Marine Environment Management Act".

Based on the "Act on the Promotion of the Development, Use and Diffusion of New and Renewable Energy", the Ministry of Trade, Industry and Energy could enforce the obligatory appliance of the renewable energy resources for public buildings. The thermal ocean energy for the air conditioning was approved to be one of the renewable

energy resources, executing the renewable installation institution for public buildings in 2015.

MARKET INCENTIVES

The Renewable Portfolio Standard (RPS) began in 2012, and was enforced in 13 utility companies with the capacity of over 500MW. According to the regulation, the renewable energy participated with 3.5% in the total electricity production in 2015.

The tradable Renewable Energy Certificate (REC) is a market incentive that supplements the RPS policy. The value of REC varies depending on the type of generated resources and other factors, such as distance from coastline, capacity or installation method. For example, the REC of a tidal barrage with embankment is 1.0, while the tidal barrage without embankment and tidal current is 2.0s. RECs for the wave energy and thermal ocean energy still have to be determined.

The price of the renewable energy for a domestic market is determined by the summation of the REC price and the System Marginal Price (SMP). As of March 2015, the price of the SMP and REC is 11 cents/kWh and 8 cents/kWh

PUBLIC FUNDING PROGRAMMES

The MOF and MOTIE provide public funding for RD&D and installation promotion programmes for the renewables, including the ocean energy. The RD&D programme of MOF mainly funds demonstration projects under the "Practical Ocean Energy Technology Development Programme," while the MOTIE is responsible for the fundamental R&D projects under the "New and Renewable Technology Development Programme". In addition, the MOTIE runs/manages the renewable installation promotion programme, where it partly funds the installation of the renewable related facilities. However, at the moment, ocean energy is not being considered as the part of the programme.

MARINE SPATIAL PLANNING POLICY

Although there is no specific legislation for the marine spatial planning alone, the legal base for the offshore energy power production is governed and implemented by different national and domestic authorities. The MOF has the Public Water Management & Reclamation Act (Act No. 11690, 2013), and it provides the framework and the general law governing the management of public water when installing the structure or using it.

One may install a structure in accordance with either of the Acts, but depending on their governing laws, applicable management requirements may differ. Pre-selected area for ocean energy has not been defined yet, although there are legal considerations to be made in the process of site selecting primarily by the Public Water Management & Reclamation Act and Coast Management Act. Construction of the demonstrative offshore wind turbine of Jeju Island was carried out based on the assessment above mentioned.

PERMITTING AND LICENSING PROCESS FOR OCEAN ENERGY PROJECTS

The consenting process can be classified in to 2 levels. The first consenting level is for public waters management and reclamation, which lasts for approximately 20-30 years after its development. The other consenting level is necessary for offshore construction only, which is a shorter process that lasts 2-3 years. In general, the procedures below follow the steps of the demonstrative offshore wind turbine project held on Jeju Island.

▸ Consenting process for use permit for public water (3-year process)

The initial step that the developer must take is to prepare the draft for consultation on utilization of sea areas according to the Marine Environment Management Act. Depending on the location of the project, the developer shall submit the draft of summaries of the business plan, environment of area, impact forecast/analysis, possible impact to stakeholders and compensation, alternative solution, etc., to the regional authorities and residents for their consultation and approval. After the authorizing institution gives approval to the business plan, the developer shall proceed to the Marine Environmental Impact Assessment. The developer then must obtain permission for occupancy or use of public waters from the management agency of public waters, as prescribed by the presidential degree (Act No. 11690, 2013).

▸ Consenting process for permit for energy development (1-year process)

During the pre-construction stage, a business license shall be obtained from the MOTIE with consultation from Korea Power Exchange (KPX) and Korea Electric Corporation (KEPCO). In case one intends to run an electric utility, the developer shall obtain license to generate by type of the electric utility from the Minister of MOTIE (Electric Utility Act). The electric source developer shall establish an execution plan for electric source development business, and shall obtain authorization from the MOTIE when they are generating more than 3,000kW. If lower than 3,000kW, permission can be obtained from the governor of the region. Then, the developer should obtain permission for the actual construction of the offshore

structure from both MOTIE and local government. After the grid connection, the developer must demonstrate, test and report for starting new business.

▸ **Environmental Impact Assessment (EIA)**

EIA is required before and after construction according to the Environmental Impact Assessment Act, the Framework Act on Environmental Policy, and the Marine Environment Management Act, depending on the scale and location of development. According to the Environment Impact Assessment Act, the target projects for EIA are electric power plants with capacity of 10,000kW, solar/wind power plants of 100,000kW, submarine mining sites of 300,000 m^2, public water reclamations over 300,000 m^2 (over 30,000 m^2 in protected area) etc. and projects of smaller scale are target of Prior Examination of Environmental Nature. As for the post-construction monitoring system, an agent for assessment shall report the record of performance to the agency for the assessment of environmental impacts of the preceding year to the Minister of Environment. This may continue for a minimum of 5 years after construction, depending on the results.

▸ **Public Consultation**

Public consultation is required from a number of stakeholders in advance. These include the Ministry of Environment and the management agency of public waters such as the Minister of MOF, regional maritime affairs & port office, city mayor, county governor and urban district head. The most critical consultation that the developer should consider is the agreement of residents. In the process of obtaining the Use Permit of Public Waters, as prescribed by Presidential Decree, the developer should circulate the information to local residents for more than 20 days, and hold an explanatory meeting or a public hearing, if more than 30 people require it. The signed agreement from the inhabitants in the area must be included in the documents for the Use Permit of Public Waters, thus the entire process may be deterred at this stage if the developer fails to reach an agreement.

TEST SITES

The feasibility study for the construction of test beds for the wave and the tidal energy devices has been carried out, which mainly details plans to utilize the newly built demonstrative ocean energy plant sites as possible sea test sites. The areas that are suggested to be used as test beds include the Uldolmok tidal power plant, Yongsoo OWC wave energy plant on Jeju Island, and Goseong ocean thermal energy plant. There is no active sea test site that is currently open for use in the Republic of Korea (ROK). However, a construction of the wave energy test bed of 5MW capacity with 5 berths will begin in 2016.

RESEARCH & DEVELOPMENT

TIDAL ENERGY RD&D INSTITUTIONS AND PROJECTS

Project (Charged by, Funded by)	Type of Converter	Structure	Power Capacity	Project Period	Remarks
MW Class Tidal Current Device (HHI, MOTIE)	Pitch Contro	Pile	>2X500 kW	2010-2015	Sea Test in 2014
Active Control Tidal Current System (KIOST, MOF)	HAT with Pitch Control	Caisson	200 kW	2011-2018	Sea Test in 2016
Semi-active Flow Control Turbine (Inha Univ., MOTIE)	HAT with Flow Control	Moored Submersible	10 kW	2013-2016	Based on CFD
Active Impeller Tidal Turbine System (Daum Eng., MOTIE)	Vertical Impeller with Flow Control	Pre-cast Concrete	50 kW	2013-2016	Sea Test in 2016

HHI: Hyundai Heavy Industry Co., Ltd.
MOTIE: Ministry of Trade, Industry and Energy
KIOST: Korea Institute of Ocean Science and Technology
MOF: Ministry of Oceans and Fisheries

WAVE ENERGY RD&D INSTITUTIONS AND PROJECTS

Project (Charged by, Funded by)	Type of Converter	Structure	Power Capacity	Project Period	Remarks
Yongsoo OWC with Dual System (KRISO, MOF)	OWC with Impulse Turbines	Gravity Caisson	2X250 kW	2003-2016	Started Test in 2015
Pendulum WEC Utilizing Standing Waves (KRISO, MOF)	Oscillating Surge	Floating Twin Hull	300 kW	2010-2018	Sea Test of Pilot Plant in 2017
Swinging Semi-Sphere with Hinged Arm (Hwa Jin Co., MOTIE)	Floating Point Absorber	Jack-up Platform	Expandable 15 kW Units	2013-2016	Sea Test in 2016
Controllable Resonant WEC with Yoyo Oscillator (iKR, MOTIE)	Point Absorber with Variable Spring Stiffness	Moored Array of Cylinders	10 kW	2013-2016	Sea Test in 2016
WEC for Navigational Lighting Buoy (KPM, MOTIE)	Point Absorber with Solenoid	Single Point Moored Buoy	50 W	2013-2016	Sea Test in 2016
INWave WEC with Multi Degree of Motion Converting Pulleys (Ingine Inc., MOTIE)	Point Absorber with Pulleys	Floating Disk with Touted Mooring Lines	135kW	2014-2017	Sea Test in 2016

KMOU: Korea Maritime and Ocean University
KPM: Korea Plant Management Company
KRISO: Korea Research Institute of Ships & Ocean Engineering
MOF: Ministry of Oceans and Fisheries

OTEC, SALINITY GRADIENT & OTHER OCEAN ENERGY RD&D PROJECTS

Project (Charged by, Funded by)	Project Period	Remarks
OTEC Using Deep Ocean Water (KRISO, MOF)	2010-2015	Cooling & heating system of 60RT in 2011, 500RT in 2012 and 1,000RT in 2013 OTEC pilot plant of 20kW in 2013 and 200kW in 2014
Hybrid OTEC Using Plant Array (KEPRI, MOTIE)	2010-2015	Use of cooling water discharged from pilot power plant of 10kW in 2015
Establishment of Infra System for Ocean Energy (KAIST, MOTIE)	2011-2016	Education programme for ocean energy experts in graduate school
Low Temperature Working Fluid and Radial Flow Turbine for OTEC (KMOU, MOTIE)	2011-2015	Design of organic Rankine cycle radial flow turbine for 200kW OTEC using low temperature working fluid
10MW Class Floating Wave-Offshore Wind Hybrid Power Generation System (KRISO, MOF)	2011-2016	Development of analysis technologies and optimal design of a pilot plant for a hybrid ocean energy system with multiple FOWTs and WECs
Key Technologies of RED Stack for salinity gradient utilization (KERI, MOTIE)	2014-2017	Development of reverse electro dialysis stack and optimized ion-exchange membrane for kW-class salinity gradient power generation
Ocean Energy Professional Development Programme (Inha Univ. MOF)	2014-2018	MOF programme promoting ocean energy education, research and development in universities

KAIST: Korea Advanced Institute of Science and Technology
KEPRI: Korea Electric Power Research Institute
KERI: Korea Energy Research Institute
KMOU: Korea Maritime and Ocean University
KRISO: Korea Research Institute of Ships & Ocean Engineering
MOF: Ministry of Oceans and Fisheries
MOTIE: Ministry of Trade, Industry and Energy

TECHNOLOGY DEMONSTRATION

OPERATIONAL PROJECTS

The 200kW High Temperature-Difference Ocean Thermal Energy Conversion (H-OTEC) by KRISO in Goseong was completed in December 2014. The performance assessment for the 200kW H-OTEC plant was carried out by the qualified institute, the cycle efficiency was shown as 7.7% under the 70°C temperature differences. It is in the process of utilizing an unused energy such as geothermal heat around coast area and waste heat from combined heat and power plant. Seawater heat pump systems of 500RT (1750kW) and 100RT (350kW) to supply the cooling and heating energy were installed for the abalone and fish aquaculture facilities, which use the effluent discharged from power plant and coastal seawater, respectively.

INWave, a point absorbing developed by INGINE Inc., was installed in Jeju costal water in 2015. The pilot plant of 135 kW capacity is currently in commissioning stage and will be connected to local grid in March 2016. The INWave system increases energy absorbing efficiency by utilizing both vertical and horizontal movements of disk-like buoys, which are connected by energy converting pulleys.

200kW H-OTEC in Goseong

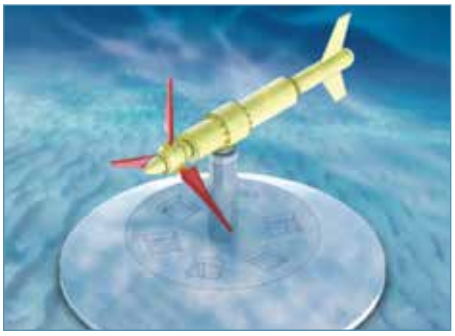
135kW INWave on Jeju

PLANNED DEPLOYMENTS

The process of updating the 300kW wave energy converter is being continued by KRISO and MOF as the pilot plant of a pendulum-activated floating WEC is currently being constructed in a shipyard for sea test in 2017. The system is featured by a robust rotary-vane hydraulic pump which is greatly durable under the repeated wave impact.

An active-controlled tidal energy converter has been developed by KIOST since 2011 and its detail design was completed in 2015. It is expected that the pilot plant of 200kW will be installed for sea test in 2016. The system is applicable to shallow sea conditions (>20m).

The project for the establishment, installation and operation of 1MW OTEC plant will be launched in mid- 2016 by KRISO and MOF. The plant will be operated in the area of the equatorial Pacific Ocean as the suitable overseas location. The development project is expected to be completed by 2020.



OTHER RELEVANT NATIONAL ACTIVITIES

Solar, Wind & Earth Energy Trade Fair (SWEET) is a specialized fair on new and renewable energy. This annual fair was first held in 2006 and has grown in size and number of participants, as it held 194 companies from 14 countries in 2014. The main focus of the fair is to support the investment plan for new and renewable energy industry of ROK and provide opportunity for participants of worldwide companies and experts specialized in new and renewable energy, where they can exchange ideas and information. Among various classifications of new and renewable energy, the exhibition contains tidal power generation, wave power generation, and OTEC.

SINGAPORE

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

INTRODUCTORY NOTE

The city-state is well known as a clean and green city which strives for environmentally sustainable development, with a continuously growing economy (Tay, 2015). For the past few years, it has shown significant interest in renewable energy research, development and demonstration (RD&D), including in ocean renewable energy (ORE). Singapore has provided a conducive environment for ORE to be further developed, through support from the Government in establishing various marine renewable energy test beds, encouraging collaborative projects among academic research organisations, industries and Government agencies, and providing funding and resources for highly innovative ORE technologies.

The Renewable Energy Integration Demonstrator-Singapore (REIDS) project aims to test and demonstrate, in a large scale microgrid 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 National Environment Agency (NEA), was officially launched in October 2014 with ten industry partners and 2015 marked the start of key onshore and offshore projects. A test site for tropical tidal turbines will contribute to the offshore component of REIDS.

In terms of regional collaboration, the Southeast Asian Collaboration for Ocean Renewable Energy (SEAcORE) is a platform initiated by the Energy Research Institute @ NTU (ERI@N) with partners from Southeast Asia to promote ocean renewables and create new markets for partner industrial firms (ERI@N Report, 2012-2014). This year, SEAcORE has been officially recognised by the Asian Centre for Energy (ACE) as its technical working group for offshore renewables – spearheading technology assessment and resource mapping methodology guidelines in projects involving marine resource assessment and turbine systems identification suitable for tropical conditions.

In addition, there are efforts to drive the commercialisation of ORE. OceanPixel is a Singapore start-up company that spun off from NTU, through ERI@N's Wind and Marine team. It has positioned itself as the pioneer company dedicated to ORE in the Southeast Asian region. Several resource assessment and techno-economic feasibility projects between Singapore and other Southeast Asian countries including Indonesia and the Philippines are currently on-going through OceanPixel.

2015 marked the successful completion of different marine-related projects and a stronger commitment towards more innovative and effective means of fully utilising ocean energy sources and technology in Singapore.

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). 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 have been set aside by the Singapore Government for research in energy, water, green buildings, and addressing land scarcity of which S$140 million are 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 by ERI@N as a strategic research area.

Singapore, being a small city-state, develops its own solutions to address constraints in land and water resources by building partnerships between public agencies 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 and its research centres have considerable expertise and strength in areas of offshore energy which include wind, wave and tidal energy and complementary technologies such as energy storage, microgrids, 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 commercialisation 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.

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 microgrid 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 seabed conditions and tidal current measurements", and to evaluate and test bed commercially ready turbine in Singapore waters.

Sentosa-ERI@N Tidal Test Site

The Sentosa Tidal Test Site is a joint collaboration between Sentosa Development Corporation (SDC) and ERI@N, funded by the Ministry of Trade and Industry's Core Innovation Fund. This project aims to showcase tidal energy extraction as a feasible and sustainable energy generating technology in Singapore and to provide opportunities to develop local technologies to harness the energy available in the narrow channel between Singapore and Sentosa. In November 2013, ERI@N and SDC officially launched the Sentosa Tidal Test Site (NTU, 2013).

Recent developments on the project include the deployment of scaled tidal turbines supported from the floating barges. Also, novel concepts such as vortex induced vibrating devices are being evaluated for field performance along with anti-biofouling coatings. The power developed is used for electric lighting on the boardwalk.

Floating hinged turbine support frame to house tidal turbines and vortex induced vibration devices. (Left) & Scaled (1:3) tidal turbine in tow tank (Right)

Marine Renewable Energy at Tanah Merah Ferry Terminal

The "Tidal-In Stream and Wave Energy Resource Assessment" project has successfully been concluded this year. This project has been funded under the Maritime Clean Energy Research Programme (MCERP) driven by the Maritime Port Authority (MPA) and NTU. The project aimed to undertake a feasibility study, device development and prototype installation at Tanah Merah Ferry Terminal (TMFT) in Singapore.

The marine renewable energy resources (tidal: range and currents - tidal in-stream, and wave energy) have been assessed, characterized, and analysed to determine the extraction potential at TMFT. Specifically, a wave energy conversion module making use of the floating pontoon, which has an area averaging feature for wave energy capture, has been developed, installed, and tested/characterized at one of the TMFT jetty berths.

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 microgrid will facilitate the development and commercialisation 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*: This 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 photovoltaics, wind, tidal, energy storage, bioenergy, innovative water desalination, hydrogen production, etc.

- *REIDS Offshore: Tropical Marine Energy Centre (TMEC)*: While several high energy potential locations, associated with strong tidal currents, in Europe, North America and North Asia have long been identified and harnessed, the tropical markets for lower-tidal-velocity distributed generation, for instance in Southeast Asia, are yet to be explored. As there is no full scale or even scale test site yet in the region, it is challenging to test and develop tidal turbines, especially tidal turbines that can be used optimally in the tropical conditions. As a result, the TMEC project initiated by ERI@N and supported by ClassNK 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 mid-2016. This study involves an investment of more than S$2 million. Presently, an environmental impact assessment (EIA) for the test sites is being carried out.

STANDARDS FORMATION PARTICIPATION FOR OCEAN RENEWABLE ENERGY

ERI@N has initiated participation in the International Electrotechnical Commission's "Marine energy – Wave, tidal and other water current converters" standards technical committee IEC-TC114 through SPRING Singapore, the official body responsible for standards within Singapore. SPRING, with ERI@N's help, is currently in the process of forming the National Mirror Committee (NMC) for Singapore. The NMC seeks to review, adapt, and propose guidelines for

Marine Energy in Singapore and serves as a stepping stone for possible adoption towards international standards specific for tropical regions such as Southeast Asia.

PARTICIPATION IN COLLABORATIVE INTERNATIONAL PROJECTS

ClassNK – Global Research and Innovation Centre in Singapore

ClassNK, a Japanese ship classification and certification society, and the Maritime Port Authority of Singapore (MPA) have signed a Memorandum of Understanding (MoU) on 13 February 2015 "to promote research and development and innovation in the maritime industry" (MPA, 2015). The signing also marked the opening of the Global Research and Innovation Centre (GRIC) in Singapore, which will focus on two main sectors – 1) Maritime technologies and 2) Marine renewable energy. For marine renewables, the GRIC aims to "establish a marine energy test site for the tropics to support R&D in energy storage systems, biofouling materials, energy converters, prototype design testing, and creating possibilities to provide energy for maritime industry usage in ports and harbours" (offshoreWind.biz, 2015).

Joint PhD - Industry Programme (JIP)

ERI@N has been actively engaging, partnering and collaborating with industry through its JIP projects. The JIP involves local and global academic partners, research agencies of Singapore and multi-national firms which are engaged in cutting-edge research into various aspects of offshore renewable energy, technology development and commercialisation. The technology advancement is achieved through doctoral projects that are directly involving sponsoring firms' participation to address real life technology challenges. Presently, more than 20 doctoral projects are in progress. As part of the technology advancement efforts, NTU is teaming up with Technical University of Munich (TUM) to setup an International Centre for Energy Research (ICER).

Southeast Asian Collaboration for Ocean Renewable Energy (SEAcORE)

This year, SEAcORE has been officially named as the technical working group for offshore renewables under the Renewable Energy Sub-sector Network (RE-SSN) of the Association of Southeast Asian Nations (ASEAN) Centre for Energy (ACE). As a technical working group, the SEAcORE network will work with ACE on providing quality research on offshore renewable energy and its technological solutions, techno-economic and policy aspects towards Southeast Asian regional energy security needs. In addition, there is a focus on human resources and capacity building activities on offshore renewables. SEAcORE involves collaboration between neighbouring countries, including Brunei, Indonesia, Malaysia, Myanmar, Philippines, Thailand and Vietnam. This provides a platform for the exchange of ideas, initiatives, and experiences from R&D, policy makers, and industry on the offshore/ocean-related field.

Outreach Programmes

In line with Singapore's interest to promote sustainable energy solutions for the tropical region, ERI@N is involved in developing and test bedding tidal in-stream energy systems for island microgrids. One current project is the deployment of a floating tidal turbine system on a remote industrial island in West Papua. The collaboration involves Green Forest Product and Technology Pte Ltd (a sustainable mangrove harvesting firm), Schottel Hydro GmbH (a tidal turbine technology provider), OceanPixel Pte Ltd, and ERI@N. The island microgrid 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.

Dr. Sanjayan Velautham, Executive Director of ACE and Dr. Srikanth signing the MoU during the ACES.

Also as part of the outreach, ERI@N participated in the International Renewable Energy Agency's (IRENA) marine energy workshop for SIDS (Small Island Developing States) towards promoting ocean renewables for islandic energy needs.

ERI@N has also taken part in the Indian Ocean Regional Association (IORA) to discuss Blue Economy initiatives, which involve nations' efforts towards exploiting ocean resources such as energy, minerals, food, medicine, etc. Countries such as India, Russia, Indonesia, France and other IORA members have also participated. ERI@N has highlighted how marine renewables can enable energy security, generate job creation, and provide technology alternatives, economic growth and environmental protection.

Regional Network and International Conferences towards increasing ORE Uptake in SEA

Regional Technological Roadmap on Ocean Renewable Energy

ERI@N has partnered with University of Edinburgh (UK), Cardinal Engineering (US) and Power Projects Ltd (Australasia) to come up with a global technology roadmap for ORE. The main objective of this technological roadmap is to understand barriers towards ocean energy technology adoption and explore pathways and strategies to overcome barriers and support cost reduction of ocean renewable energy technologies in order to achieve competitive levelised cost of energy in comparison with other sources of energy. The report is designed to influence OES members, mainly the public and private technology funders to give them advice regarding R&D prioritization.

Asia Clean Energy Summit (ACES) 2015

The annual Asia Clean Energy Summit (ACES), an event during the Singapore International Energy Week (SIEW) organised by the Energy Market Authority of Singapore (EMA), was held in October 2015. The ERI@N Wind and Marine team was involved as the technical team for the offshore renewable energy (RE) track.

Asian Wave and Tidal Energy Conference (AWTEC) 2016

Singapore has been chosen to host the next Asian Wave and Tidal Energy Conference (AWTEC) in 2016 (AWTEC, 2014). AWTEC is to be held on 24 -28 October 2016 in conjunction with the popular SIEW 2016 at the Marina Bay Sands, Singapore. ERI@N heads the Local Organising Committee and along with experts from Japan, Korea, UK and Australia, the team will run the conference, providing opportunity to showcase ocean technology development efforts and innovative solutions with greater regional impact and broader reach.

For more information please visit: www.awtec.asia/conferences/awtec-2016

TECHNOLOGY DEMONSTRATION

ERI@N has designed, prototyped, and installed a Wave Energy Converter (WEC) for harnessing the jetty berth's pontoon movement due to waves and converting the mechanical power into electrical power. The WEC is presently coupled with its own roller as a system which is separated from existing pontoon rollers to ensure the safety of pontoon operations. Eventually the whole system will substitute the existing support rollers to function as both pontoon movement guides and energy extraction devices.

The technology developed in this project can be further matured from the initial proof-of-concept to the proof-of-value stage through collaboration with an industry partner, which can commercialise the product. A funding support scheme could then help to take this forward. The application of such technology is not limited to shore based installations - it can be further extended to use in ships and other marine vessels and installations (e.g. offshore rigs, aquaculture platforms, etc.).

Existing roller, pontoon, and jetty berth at Tanah Merah Ferry Terminal

SPAIN

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

INTRODUCTORY NOTE

Ocean Energy is progressing in Spain with the consolidation of three open sea test sites: *bimep* and the flagship wave power plant at Mutriku with over 1GWh of cumulative produced power so far in the Basque Country and PLOCAN on the Canary Islands. A couple of wave energy technologies under development by Wedge Global and OCEANTEC and several research projects led by TECNALIA complement the Spanish ocean energy landscape.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The Spanish Renewable Energy Plan 2011-2020, approved in 2011, 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 also in 2011 its Energy Strategy for 2020, which included a specific initiative to speed up technology and commercial development of wave energy and set a target of 60MW by 2020.

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 amended the previous Coastal Law of 1988. It provides the legal framework for occupation of the territorial sea, as well as governing issues affecting the fishing sector and safety conditions for maritime navigation.
- Law 21/2013, of 9 December, establishes a simplified process on Environmental Impact Assessment for all marine energy projects.

MARKET INCENTIVES

In November 2014, the Basque Energy Agency (EVE) launched a tender of a pre-commercial public procurement for the development of a floating wave energy converter suitable for the Basque coast. In November 2015, OCEANTEC, a Spanish company with two shareholders (Iberdrola and TECNALIA) was awarded by EVE to supply its technology based on a floating oscillating water column concept. This €2.5 million contract will allow OCEANTEC moving forward into a TRL7 stage after testing, during one year, of a low power prototype connected to the grid at *bimep*.

PUBLIC FUNDING PROGRAMMES

There are several public funding programmes in Spain for research and technology development no specific for ocean energy but applicable for ocean energy in competition with other sectors. However there are a couple of programmes more specific for ocean energy:

- The Spanish Government, through CDTI (the Centre for the Development of Industrial Technology), together with four

regional governments (Asturias, Cantabria, Basque Country and the Canary Islands), has joined the European network OCEANERA-NET to coordinate funding programmes between European countries and regions to support research and innovation in the ocean energy sector. Three projects have been funded in Spain under the first OCEANERA-NET call and more opportunities will come with the second call expected in 2016.

▸ In the Basque Country, a new call to support open sea testing was launched by EVE in 2015. The purpose of this programme is the demonstration and validation of emerging marine renewable energy technologies.

MARINE SPATIAL PLANNING POLICY

There is no a specific Marine Spatial Planning (MSP) policy in Spain. Pre-selected areas for ocean energy development have not been defined. Site selection is carried out on a case by case basis. In the Basque Country, in the case of *bimep*, a MSP approach has been used for selecting the site.

PERMITTING AND LICENSING PROCESS FOR OCEAN ENERGY PROJECTS

The total time needed to obtain approval of an ocean energy project in Spain is approximately two years but this timeframe can vary depending whether an Environmental Impact Assessment is required or not. The new environmental law in Spain aims to reduce the time scale needed for obtaining the Environmental Authorisation, establishing a time period of no more than 4 months, or 6 months if there are justified reasons, thus reducing significantly the time needed for this consenting process.

Spain, with the participation of AZTI-Tecnalia, is working with other European countries on the **RICORE** project (Risk Based Consenting for Offshore Renewables). The aim of this project is to establish a risk-based approach to consenting where the level of survey requirement is based on the environmental sensitivity of the site, the risk profile of the technology and the scale of the proposed project. The project, which has received funding from the European Union's Horizon 2020 research and innovation programme, will run between 1 January 2015 and 30 June 2016

TEST SITES

The Biscay Marine Energy Platform (*bimep*), an open sea test facility promoted by EVE and IDAE (Institute for Energy Diversification and Saving) in the Basque Country, was officially inaugurated in July 2015 and is now working with the first users who will shortly install several trial devices. An innovative public procurement was tendered by *bimep* in November 2015 to develop and install a submarine hub for electrical connection.

After the start-up of *bimep*, EVE is giving **Mutriku**'s wave power plant a new use as test site, which is compatible with the main activity of the plant, that is, to generate electricity from wave energy.

PLOCAN offers a marine test site for marine energy converters. The submarine electrical infrastructure is still in the design stage. It will be ready during the first trimester of 2017 offering the required grid connection. The initial capacity is set at 15 MW with a future extension planned up to 50 MW by 2020. The PLOCAN test site was authorized by the Cabinet of Ministers in March 2014 including a marine area of 23 km^2 from the coast to 600 m depth.

RESEARCH & DEVELOPMENT

Within the OCEANERA-NET programme, TECNALIA is leading a consortium with partners from Spain, Portugal Ireland and UK to develop and demonstrate critical components for monitoring, control and electrical connection for ocean energy. Delivering reliable and cost-effective technologies will be paramount to the ultimate commercial success of Europe's ocean energy industry. The so called **RECODE** project aims to give answer to this challenge by developing a set of industry-enabling cost-effective components, specifically designed for reliable and sustainable delivery of ocean energy arrays. The project started in October 2015 and will run for three years.

TECNALIA, in collaboration with OCEANTEC, was awarded £87,271 by Wave Energy Scotland under its first competitive open call for innovative Power Take-Off (PTO) systems for wave energy. The project **SEÒLTA** (Survivable and Efficient OLeo-hydraulic assisted Power Take-off) aims at producing a step change in

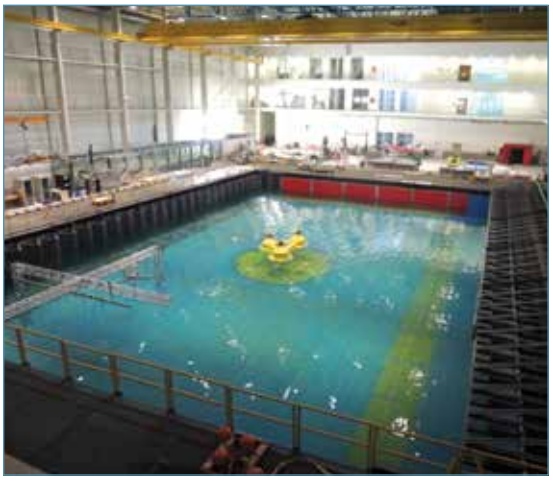
the overall performance of PTO systems used for wave energy harvesting. Particularly, this project phase will characterise and assess the feasibility to wave energy of a novel hybrid PTO configuration that is directly inspired on those used in the automotive sector, which have achieved a significant reduction on fuel consumption (in the range of 30-50%).

In November 2015, 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 and DNV, signed a contract with the European Commission under the Horizon 2020 programme to develop the project **OPERA** (Open Sea Operating Experience to Reduce Wave Energy Cost). OPERA will collect and share two years of open sea operating data of a floating oscillating water column wave energy converter. In addition, the project 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.

TECNALIA is also 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) and to increase the impact of this research into the local industry.

Abengoa Seapower continues the development of several activities in ocean energy, including R&D projects in wave and tidal energy, engineering for construction of marine energy projects, and the development of different tools mainly focused on grid and performance of marine energy devices.

Ecoboya's prototoype during sea trials at the mouth of the Guadalquivir river.



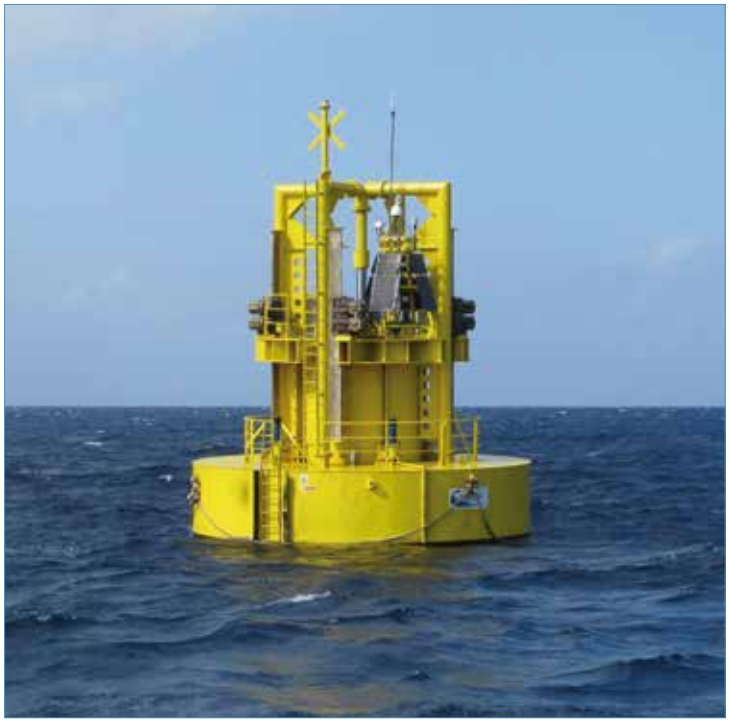
Tank testing campaign of the Undiplat's 1:20 scale prototype.

Furthermore, Abengoa Seapower's team has performed a successfully tank testing campaign on a 1:20 scale prototype (TRL 04) of its own wave energy device, Undiplat, based on a multiple oscillating water column (OWC) system. The 1:4 scale prototype (TRL 05) is expected to be tested off the north coast of Spain by the end of 2017 before the development of a full scale prototype.

TECHNOLOGY DEMONSTRATION

OPERATIONAL PROJECTS

After 4 years of continuous operation with a cumulative production of over 1GWh, Mutriku Wave Power Plant is now ready to host tests related to new concepts of OWC systems (air turbines, electrical generators and control systems). Wedge Global is leading UNDIGEN+ project based on the industrial scale W1 device. The W1 system is an axisymmetric resonant point absorber with direct drive (linear generator) Power Take-Off and incorporates ten years of technology development and testing. During 2015, the W1 system has kept on testing under open sea tests in the Atlantic Ocean at PLOCAN site (II Phase) as well as testing at the harbour on the Canary Islands (achieving current non-stop ocean tests since January 2014), with promissory effective generation results. UNDIGEN+ is a 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.** After the satisfactory completion of the planned tests during 2015, and due to the outstanding performance of the system, additional tests have been planned for 2016 (III Phase).



Wedge Global W1 prototype

The Finnish company **WELLO** installed the PENGUIN II prototype in September 2015. The objective of this first experiment is to test the structural reliability of a 6m length and 2,4m width device constructed in Finland and assembled at the Taliarte harbour close to PLOCAN headquarters. The testing phase will be extended through 2016.

PENGUIN II device

PLANNED DEPLOYMENTS

OCEANTEC plans to install a low power prototype of its floating oscillating column water wave energy converter connected to the grid at *bimep* in mid-2016.

The **Magallanes** project was launched in 2007 setting out to develop a technology capable of extracting energy from tidal currents. The project is in the final stage of assembly and construction of a real scale prototype, 350 tons of weight. Sea trials are expected in 2016. Following a research and development stage, in 2014 Magallanes built and tested a 1:10 scale model, successfully completing official testing at EMEC in Scotland. The technology is based on a floating structure without requiring constructions or pillars in the marine bottom. The project is based on achieving the most efficient, profitable method possible to obtain tidal energy: a sturdily-built, simple installation, capable of producing in any area in the world, with the easiest maintenance system.

OTHER RELEVANT NATIONAL ACTIVITIES

The second edition of the southern Europe's largest marine energy conference was held in Bilbao in April 2015. **Bilbao Marine Energy Week,** organized by EVE, TECNALIA and the Bilbao Exhibition Centre, was attended by around 600 experts from leading agents, companies, researchers and decision-makers involved in the development of marine energy technology and projects. The organisers of BMEW15 are already working on a new edition in 2017.

The **APPA-Marina** team has worked hard on multiple fronts during 2015 representing the interests of the marine energy industry in Spain. APPA-Marina, jointly with the Naval Engineering School of Madrid and CME (Spanish Maritime Cluster), organized the National Annual Meeting in Madrid in November 2015. Test centre representatives, Government officials, researchers and industry leaders have 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 energies. Its main objective is to bring together Central and Regional Governments, R&D institutions and industrial companies interested in the development of the ocean energies.

SWEDEN

MARIA OLSSON *Swedish Energy Agency*

INTRODUCTORY NOTE

During 2015, the Sotenäs project, which is planned to become one of the largest wave energy parks in the world, progressed. In the end of 2015, all 36 generators for the first stage were in place, and the subsea generator switchgear was deployed and connected to the Swedish national grid. The wave park, situated at the Swedish west coast, will start producing electricity to the grid as soon as the buoys are connected to the generators.

Several other Swedish development companies have made progress during the year and are preparing for demonstration of their techniques in the ocean. Finally the wave energy research site Lysekil has been grid connected during 2015.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The Swedish energy policy is based on the same foundations as the energy cooperation in the European Union (EU) and seeks to reconcile environmental sustainability, competitiveness and security of supply. The vision is that, by 2050, Sweden has a sustainable and resource efficient supply of energy and no net emissions of greenhouse gases in the atmosphere.

In order to realize the vision and implement the EU 20-20-20-targets, the following national targets for renewable energy, reduction of carbon emission and efficient use of energy in Sweden by 2020 have been set:

- The share of renewable energy in 2020 should be at least 50 percent of total energy use.
- The share of renewable energy in the transport sector should also be at least 10 percent.
- A 40% reduction in greenhouse gas emissions from 1990 levels.
- A further goal is 20 percent more efficient energy use in 2020, expressed as a reduction in energy intensity of 20 percent between the years 2008-2020.

The forecast for Sweden in 2015 is that in 2020 the first three goals will be achieved with margin, while the last goal concerning efficient energy use is more uncertain.

In 2015, the Ministry of Enterprises, Energy and Communications finished the 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. A summary in English can be found here: http://www.government.se/contentassets/9e9c9007f0944165855630ab4f59de01/a-swedish-maritime-strategy--for-people-jobs-and-the-environment

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. While wave energy is one of the renewable energy sources for which producers would be eligible for certificates, none has been issued so far.
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, the annual production from renewable sources in 2020 shall have increased by 28,4 TWh relative to production in 2012.

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. In the first call, 7 projects were approved of funding. There were companies, institute and universities involved in the projects and they covered topics such as environmental assessment, technology development, improvement of models, etc. A second call has recently opened.

MARINE SPATIAL PLANNING POLICY

The Swedish Agency for Marine and Water Management is preparing the forthcoming national marine spatial plans. The marine spatial plans will provide guidance for authorities and municipalities when planning for where different activities can take place. The marine spatial plans will be directional (non-binding) during the consenting process, although the Government may adopt separate binding regulations linked to the plans prohibiting or limiting activities in destined geographical areas. During 2015, a proposal for the direction of marine spatial planning has been developed in order to clarify and support the continuing work.

TEST SITES

There are two research sites in Sweden, Lysekil wave power research site and Söderfors marine currents research site. Both sites are operated by Uppsala University. Interest has been expressed to expand the Lysekil wave power research site and thus allow access to other universities and developers from Sweden and Europe.

RESEARCH & DEVELOPMENT

UPPSALA UNIVERSITY

The Division of Electricity at Uppsala University conducts research on wave energy technology and hydrokinetic energy conversion from tidal currents and rivers. Today, the wave power research group consists of 19 PhD students and 13 senior researchers. Uppsala University operates two research sites: Lysekil wave power research site and Söderfors marine current research site. The Swedish Energy Agency is supporting some theoretical and experimental works related to the Lysekil project, as well as some theoretical work behind the Söderfors project:

- **The Lysekil project:** During 2015, the Lysekil research site was grid connected. Further on, two WECs were

deployed and operated. A new signal cable has been installed between the measurement cabin and marine substation. Preparations have been made for installation of a sonar system for marine environmental, as well as technical monitoring; a new echo-sounder is also ready to be deployed. A force measurement buoy has been installed with the purpose to measure the wave forces during storms.

▸ **Söderfors project:** The Söderfors marine currents research site is located in Dalälven River and consist of a 7,5 kW vertical axis turbine with a directly driven permanent generator. It is connected to a measurement cabin on land. Preparations for grid connection are in progress.

Two new research projects have started recently financed by the Swedish Energy Agency. One is about studying and improving performance and survivability of large scale wave energy farms. The other project is about studying fish and crustaceans (ecosystem services) in relation to wave energy installation.

Söderfors project, when the marine current energy converter was being deployed

CHALMERS UNIVERSITY OF TECHNOLOGY

Research in marine renewables is mainly performed at the Department of Shipping and Marine Technology and at the Department of Energy and Environment. The research can be broadly divided into hydrodynamics, structures, energy conversion, environment and industrialization:

▸ Hydrodynamics: Chalmers are carrying out several projects in the use of nonlinear hydrodynamic simulations using CFD, fully nonlinear potential flow solver and asymptotic wave equations.
- In a recently finished project supported by the Region of Västra Götaland a method to perform coupled mooring analysis using CFD was developed. This work is extended in a project funded by the Swedish Energy Agency.
- Chalmers is partner in the MIDWEST project, approved by the OCEANERA-Net consortia, focusing on developing medium-fidelity hydrodynamic models based on Boussinesq-type wave equations and multi-fidelity optimization.

▸ Structural dynamics: Chalmers work in structural dynamics for wave energy applications focuses mainly on cables, both mooring cables and electrical cables.
- In a project funded by the Swedish Energy Agency, the durability of electrical cables and moorings cables used in systems for harvesting of renewable ocean energy is analysed.
- Chalmers is also partner in a Danish project (EUDP funded) that aims at designing, testing and developing cost efficient mooring solutions for large, slack moored, floating wave energy converters.

▸ Energy conversion: In a project sponsored by the Region of Västra Götaland and Chalmers Energy Initiative, life cycle cost analysis of the generator with its converter system is performed in order to find designs with low total cost.

▸ Environment: Models on fish tidal turbine collisions have been developed. The model can also be scaled up to handle arrays of turbines, making it a possible tool for marine spatial planning and management. Collaboration with the Swedish Agency for Marine and Water Management regarding marine ecological risk assessment (ERA) and models for marine spatial planning is ongoing.

▸ Marine energy resources:Research on a relatively quick method to establish the existing tidal current energy resource to identify locations for tidal energy plants has also been published.

▸ Industrialization: Chalmers are carrying out a project looking into policy for industrializing marine energy technologies.

Most projects are carried out in collaboration with technology companies, such as Waves4Power, Minesto and Wave Dragon.

Other relevant universities are Blekinge Institute of Technology that has supported the company Ocean Harvesting Technologies AB with development of simulation models and facilities for the test rig, as well as KTH Royal Institute of Technology that has supported the company CorPower Ocean AB.

SP TECHNICAL RESEARCH INSTITUTE OF SWEDEN

SP applies its competence to the development and evaluation of technologies, material, products, and processes to meet its customers' needs and provide an effective link between academic research and industry. SP consists of six business areas and several technical departments. One of many research areas are ocean energy.
Some of the projects in which SP is involved in are:

- OffshoreVäst, a cluster organisation, owned by its consortium members of dedicated companies, universities, institutes and authorities. SP acts as host organisation and its main focus is to provide support for the offshore sector in Sweden through a setup of projects and strategies. SP leads and coordinates the work package concerning offshore energy production from wind, wave and current.

- Maritime Cluster of West Sweden, the maritime sector is an area of strength and therefore a prioritized area in public efforts to create innovation platforms and infrastructures. Between 2008 and 2012 the Region of Västra Götaland was financially involved in approximately 100 projects. In an attempt to strengthen the maritime development in West Sweden, the stakeholders in the innovation system have joined forces in a maritime cluster-project. The purpose of the project is to increase innovation and business development. The method used is increased contact and collaboration between the maritime business sector and research. SP leads and coordinates the work package concerning marine energy and seafood.

- Members of Ocean Energy Europe and steering group committee of TP Ocean for the ocean energy forum.

- SP is involved in two projects - OCEANIC and RiaSoR that has been approved by OCEANERA-Net consortia. The projects focus on antifouling and reliability.

- SP is at the moment involved in two projects that have received funding from the Swedish Energy Agency with focus on reliability (structural and electrical).

SSPA SWEDEN

For 75 years SSPA Sweden has performed development in ship design and operations within the maritime sector, in close cooperation with industry and society. Several areas are related to ocean energy and SSPA has been involved in various projects in the field. SSPA's three major test facilities are also utilized in the model testing of various marine energy devices.

Together with 9 other organizations from four countries, SSPA is involved in the project Powerkite- Power Take-off System for a Subsea Tidal Kite. The project has recently been accepted and contract signed by the European Commission. Six of the parties (Minesto, SSPA, Chalmers, MoorLink, Midroc and UW Elast) are Swedish. The project intends to develop a next generation technology of tidal and ocean current power plant. The aim is to create greater experience of operation in full scale and improve structural and power performance in the energy conversion system.

TECHNOLOGY DEMONSTRATION

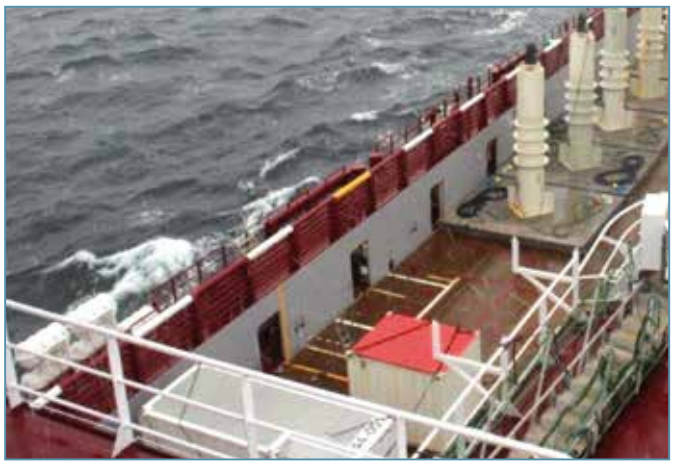
OPERATIONAL PROJECTS

The only projects that are developed and operational in Sweden, although not commercialised, are the Lysekil wave power project and the previously mentioned Söderfors marine current project. Both are operated by Uppsala University. The Lysekil wave power project installed the first wave energy converter in 2006. The installed capacity is 200 kW but with a new permission to install 20 more wave energy converters which open up for external actors

to test their technique. At least two more wave energy converters are being planned for deployment at the Lysekil research site during the first half of 2016.
For the Söderfors marine current project, the energy converter was deployed in Dalälven on 7 March 2013.

PLANNED DEPLOYMENTS

The Sotenäs Project was initiated in November 2011 and is planned to become one of the largest wave power plants in the world. When completed, it will have a total installed power of 10 MW. The technology is based on a point absorber connected to a linear generator on the sea bed.
The project is developed in two stages, in the first stage 36 wave energy converters, corresponding to 1 MW, have been deployed. In the end of 2015 the subsea generator switchgear was also deployed and connected to the Swedish national grid via a 10 km subsea cable. A number of generators have also been connected to the subsea switchgear and the wave park will consequently start producing electricity to the grid as soon as the buoys are connected to the generators.
The second 9 MW stage will be launched subsequent to the evaluation of the first 1 MW. The Sotenäs Project is funded by the Swedish Energy Agency, the power company Fortum and by Seabased Industry AB. Seabased was founded in 2001 as a spinoff from the wave energy converter research carried out at Uppsala University.
Seabased has also signed a contract for a large wave energy plant in Ghana, totalling 14 MW. The wave power plant is the first step in a facility that is expected to reach 1 000 MW when completed. The first wave energy converters and switchgear have already been delivered to Ghana and are under installation.
Seabased has also signed a Memorandum of Understanding for the development of wave energy in the Andamans in India.



Wave Energy Converters for the Sotenäs project ready for deployment

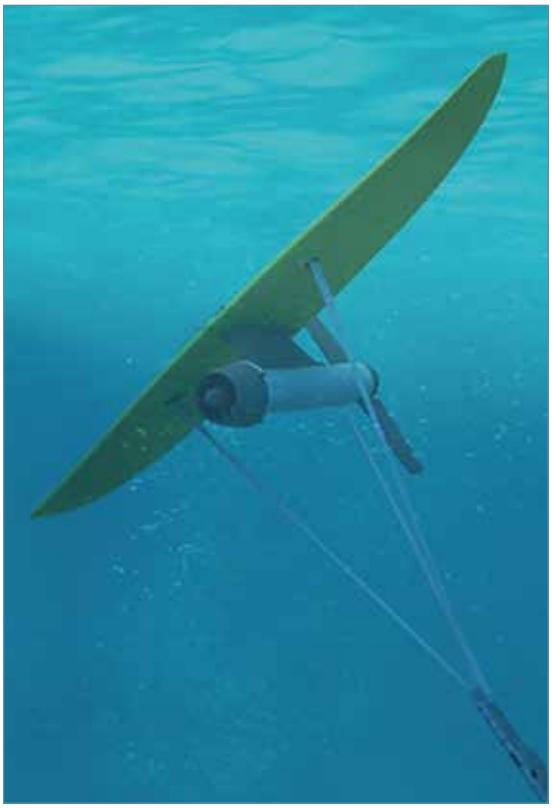
Deployment of a wave energy converter

OTHER RELEVANT DEVELOPMENT COMPANIES

There are several Swedish development companies that are progressing and are testing or will be testing their technology primarily outside Sweden. Among them are CorPower Ocean AB, Ocean Harvesting Technology AB, Minesto, Wavetube and Waves4Power.
Minesto develops a marine current technology, Deep Green, which resembles an underwater kite with a wing and a turbine. It moves swiftly in an 8-shaped trajectory in the current. A ¼ scale prototype was deployed in 2013 in Strangford Lough, Northern Ireland, and is currently undergoing extensive longtime sea trials. The next step for Deep

Green is the installation of the first commercial scale installation, a 0.5 MW power plant off the coast, in Wales, in 2017. The installation in Wales will be successively extended to a 10 MW (20 power plants) array which will eventually deliver power to over 8000 Welsh households in 2019.
The installation site is located at Holyhead Deep, Wales. They have received funding from the European Regional Development Fund through the Welsh Government and KIC Innoenergy.
Minesto has recently registered on First North at NASDAQ Stockholm.

CorPower Ocean AB has developed a Wave Energy Converter, inspired by the pumping principles ofthe human heart. Together with the Norweigan University NTNU, a new phase control technique has been developed and applied inside the buoy, which has reduced costs.
CorPower has secured funding from KIC Innoenergy and Wave Energy Scotland for a dry rig testing phase in Stockholm where the performance will be verified. This will be followed by ocean testing of a half scale prototype at the European Marine Energy Centre (EMEC) test site in Scotland in 2017. The demonstration project in the ocean is partly financed by the Swedish Energy Agency. Development, manufacturing and testing of the prototype is performed by a consortium including CorPower Ocean AB (Stockholm), Iberdrola Engineering (Glasgow) and WavEC Offshore Renewables (Lisbon). KTH (Stockholm) and NTNU (Trondheim) are involved as scientific partners.



Minesto's marine current technology

Waves4Power is a developer of buoy based wave energy converter systems. With support from the Swedish Energy Agency, Waves4Power will demonstrate a full scale prototype at Runde on the Norweigan west coast. The installation will take place in early 2016. The project will be performed in cooperation with Siemens, NKT cables, Seaflex, Blueorbis and Runde Environment Centre. The wave energy converter will be connected to the shore based power grid via subsea cable.

OTHER RELEVANT NATIONAL ACTIVITIES

Offshore Väst, which has been mentioned before, gathers several companies, universities, institutes and authorities in projects supporting the offshore sector in Sweden. Also mentioned above, the Maritime Cluster of West Sweden is a project funded by the Region of Västra Götaland and involves universities and research institutes in West Sweden. Relevant conferences taking place in Sweden are the Swedish Maritime Day and StandUp for Energy. 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. StandUp for Energy is a research alliance between Uppsala University, KTH, the 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.
In the beginning of 2015, SP held a workshop for two days at the British Embassy in Stockholm together with Innovate UK and SuperGen Marine gathering researchers in different fields of expertise.

UNITED KINGDOM

IFEDIBA EGWUATU *DECC*

INTRODUCTORY NOTE

WAVE & TIDAL STREAM

The Marine Energy sector has the potential to make a significant contribution in securing our electricity supply post 2030(50). During 2015, the tidal stream sector made significant progress, while the wave sector experienced mixed success. There was a surge of activity in the tidal stream sector with construction beginning on the world's first multi-turbine tidal stream array project MeyGen Phase 1A; tidal stream developer Atlantis' acquisition of Marine Current Turbines and the successful deployment of Tidal Energy Ltd's DeltaStream device in Ramsey Sound, Wales. 2015 saw mixed success for the wave sector, with leading UK wave energy company Aquamarine Power going into administration. However, the sector did see some success with Wave Energy Scotland (WES) awarding over £7m to technology developers and consortia following their successful first international competitive open call focussed on innovative Power Take-off (PTO) systems.

There is no doubt that the UK has world-class facilities (EMEC, Narec, WaveHub, FaBTest and the testing tanks at University of Edinburgh and Plymouth University) and a rich marine resource, coupled together with the commitment across Government and Devolved Administrations to support the continuing development of the wave and tidal stream sectors coordinated by the Low Carbon Innovation Coordination Group (LCICG)[1], and significant levels of secure revenue support in place, the UK remains an attractive location for the development of these technologies of innovative devices which attracted funding from Government bodies as well as private organisations.

TIDAL RANGE

Following renewed interest in tidal range, and particularly tidal lagoons, from developers, the Department of Energy and Climate Change has continued to explore the potential for a future tidal lagoon programme in the UK.

In March 2015, the UK Government announced it was entering into a first phase of negotiations on a Contract for Difference (CfD) for Swansea Bay Tidal Lagoon to determine whether the project is affordable and value for money for consumers, and whether it will drive down costs for tidal lagoon energy in the UK. The first phase of negotiation is a due diligence process to establish a better understanding of the project, including detailed scrutiny of its costs, timescales and potential benefits. The due diligence process is on-going.

Planning consent for the Swansea Bay Tidal Lagoon project was announced on 9 June 2015. This is only one of a number of permissions necessary before the project can proceed.

If there were to be a decision to offer a CFD, it would be subject to value for money considerations, the funds available within the Levy Control Framework at the time of a decision and to State aid approval by the European Commission.

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1. Core members of the LCICG are BIS, DECC, Carbon Trust, Energy Technologies Institute (ETI), Engineering and Physical Sciences Research Council (EPSRC), Scottish Enterprise, Scottish Government and Innovate UK.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

Work is on-going on meeting the objectives of the DECC 2013 Renewable Energy Roadmap which sets out scenarios for meeting our 2020 renewable energy targets. The latest review shows that the UK remains broadly on track to meet these. On marine energy, the focus has been working with the industry to overcome the barriers to deployment; more specifically in getting the first multi-turbine demonstration tidal array project deployed. This work continues to be delivered via the Marine Energy Programme Board (MEPB), chaired annually by the lead minister for Energy and Climate Change with policy responsibility for wave and tidal stream energy. The work of the MEPB is guided by a Programme Management Group which brings together Government and representatives of the sector. It manages a number of work-streams looking at issues critical to the progress of the sector.

Given the increasing divergence of progress towards commercial deployment of the wave and tidal stream sectors, DECCs Energy Innovation Policy team is overseeing delivery of an updated Technology Innovation Needs Assessment (TINA) for marine energy, on behalf of the LCICG. The Marine Energy TINA has been split into Wave Energy and Tidal stream TINAs. The TINAs provide a shared evidence base on the potential for cost reduction in each of eleven low carbon technologies and are a valuable tool in prioritising and coordinating innovation support. The updated Wave Energy and Tidal stream TINAs are due to be published in 2016. They will enable DECC and other government innovation funders to make effective decisions regarding how the wave and tidal stream sectors should be supported in future, based on the potential of the technology in the coming years.

WALES

The energetic waters off the Welsh coast are ideal for marine renewable energy projects and the Welsh Government has been encouraged by the growing interest in Welsh waters and the partnership approach taken to delivering projects.

The Welsh Government is working with developers to ensure that Wales can maximise the benefits and economic potential for its communities from all future operational projects. They are also working to ensure that Wales has the right skills base to support a marine industry in Wales.

The Welsh Government is working with the industry, the Crown Estate, Natural Resources Wales and key partners to overcome consenting risks and uncertainties. They also continue to work to streamline the planning system in Wales, which will benefit all future developments including those in the marine energy sector, such as the two demonstration zones being developed in Welsh waters, and four separate tidal stream projects with seabed agreements in place for locations across Wales. They are also continuing with activities in support of the Swansea Bay Tidal Lagoon Project.

In May tidal stream technology developer Minesto was awarded a 13 million Euros investment from the European Regional Development Fund through the Welsh Government. This funding will support Minesto's plans to establish its UK headquarters and install its first commercial Deep Green power plant in North Wales. In December Wales' first full-scale tidal stream generating device was deployed when tidal stream technology company Tidal Energy Ltd (TEL) successfully installed their DeltaStream device in Ramsey Sound, Pembrokeshire.

SCOTLAND

The Scottish Government remains committed to the continued development of a successful marine renewables energy industry in Scotland. The £103m Renewable Energy Investment Fund (REIF) was created to help marine projects become commercially viable. To date, REIF has invested £37.1 million in marine energy projects with further investments planned.

The Scottish public sector has invested around £23m in the MeyGen phase 1A project, forming a significant part of the total funding package (alongside DECC and The Crown Estate funding). Funding includes; £14.62m REIF investment, a 15% stake in MeyGen phase 1A by Scottish Enterprise, and a grant funding offer of £3.31 million by Highlands and Islands Enterprise. Developed by Atlantis, it is the world's largest planned tidal stream array and will have up to 400MW of installed capacity when fully constructed (269 turbines). Construction of Phase 1A (6MW) began in January 2015 with turbines expected to be installed in the middle of 2016, and first power being generated in early 2017.

Following Scottish Government establishing Wave Energy Scotland (WES) to support wave energy technology development, 2015 saw WES commit over £10 million 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.

Scotland continues to work with colleagues throughout the UK and across Europe through their membership on the British-Irish Council (BIC) and the co-leadership

they provide with DECC in taking forward the energy workstream. Scotland also plays a vital role in leadership and membership of various steering groups and workstreams including; the Ocean Energy Forum (OEF), Joint Actions Working Group (JAWG) and the Low Carbon Innovation Coordination Group (LCICG). This input is essential in identifying and addressing barriers that prevent the commercialisation of the ocean energy sector. In addition the Scottish Government is leading an Ocean ERA-NET cofund bid which will be submitted at the beginning of April 2016. The cofund supports proposals that lead to the funding of trans-national research and/or innovation projects.

NORTHERN IRELAND (NI)

The two tidal projects in Northern Ireland waters, Tidal Ventures Limited and Fairhead Tidal, continued to make good progress in 2015, working through the survey, research and stakeholder engagement activities as part of the Environmental Impact Assessment for the statutory consents and marine licences. They are also engaging with the NI Authority for Utility Regulation, NI Electricity and the System Operator for NI with regards to grid connection issues. It is expected that these projects will contribute to the Northern Ireland target of 40% renewable electricity consumption by 2020.

The Department of the Environment continued work on the Marine Plan which will help inform and guide the regulation, management, use and protection of the Northern Ireland marine area.

REGULATORY FRAMEWORK

In September 2015 The Crown Estate (TCE) began a new leasing process for seabed rights of sites up to 3MW for wave and tidal stream projects.

MARKET INCENTIVES

In the implementation of UK Government's Electricity Market Reform (EMR) programme, wave and tidal stream technologies were granted a reserved allocation of 100 MW across both the Renewables Obligation (RO) and the contract for difference (CfD) schemes, in addition to the highest strike price of any of the renewable technologies at £305/MWh. Both the reserved allocation and strike price are for deployment during the first Delivery Plan period which concludes in 2019.

NORTHERN IRELAND

Invest NI continues to work closely with companies active in the marine energy market to develop their capability to contribute to the supply chain.

PUBLIC FUNDING PROGRAMS

The main source for information on opportunities to access research and development funding for marine energy and other renewables continues to be through the Energy Generation and Supply Knowledge Transfer Network (https://connect.innovateuk.org/web/energyktn/overview).

Information on the main organisations providing funding for marine energy and other renewables can be found at the links included below:

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 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 the Department for Business, Innovation and Skills. 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

ENERGY TECHNOLOGIES INSTITUTE

The Energy Technologies Institute is a public-private partnership that brings together engineering projects that develop affordable, secure and sustainable technologies to help the UK address its long term emissions reductions targets as well as delivering nearer term benefits: http://www.eti.co.uk/

THE CARBON TRUST

The Carbon Trust offers a wide range of support for low carbon innovation mainly in the pre-market arena: http://www.carbontrust.com/home/

Other sources of public funding with scope to support research and development in the marine energy space are:
The Regional Growth Fund: https://www.gov.uk/understanding-the-regional-growth-fund

THE EUROPEAN MARINE ENERGY CENTRE (EMEC)

The European Marine Energy Centre (EMEC) is still the only accredited wave and tidal test centre for marine renewable energy in the world, suitable for testing 14 full-scale devices simultaneously in some of the harshest weather conditions while producing electricity to the national grid through the company's infrastructure.
EMEC also has two scale test sites allowing smaller scale devices or those at an earlier stage of development to gain real sea experience.
Several wave and tidal developers have continued and begun grid-connected testing of their devices at EMEC's Billia Croo and Fall of Warness sites.
In April 2015 EMEC announced plans to take part in a pilot programme that will convert the excess power generated at its tidal test site into hydrogen fuel; allowing the hydrogen gas to be stored and used at a later time.

TEST SITES

WAVE HUB

Wave Hub is a pre-installed grid connected site approximately 10 nautical miles (16km) off the north coast of Cornwall for the testing of large scale offshore renewable energy devices. The site has a Section 36 electricity consent and holds a 25 year lease for 8 kms2 of seabed divided into four separate berths. Wave Hub is owned by the UK Government Department of Business, Innovation and Skills (BIS) and operated by Wave Hub Limited on its behalf.
Following securing two demonstration zone seabed leases from The Crown Estate in Pembrokeshire (wave) and North Devon (tidal); Wave Hub have been working closely with local partners to determine industry demand for the sites and exploring funding opportunities. In December 2015 they announced they had contracted MarineSpace to provide project management support to help develop these demonstration sites.

THE FALMOUTH BAY TEST (FABTEST) SITE

FaBTest has been operating as a non-grid connected commissioning site for marine renewable energy devices since November 2011. The site is leased from The Crown Estate and has a Marine Consent for testing, subject to permits issued by Falmouth Harbour Commissioners. Operational support for the site, as well as on-going monitoring and world leading research, is provided by the Renewable Energy Group from the University of Exeter based at the nearby Penryn campus.
The University of Exeter uses the site for on-going work around resource characterisation and environmental monitoring, as well as using it to contribute to pioneering research into reliability engineering, which is focussed on the nearby South West Moorings Test Facility (SWMTF) and the Dynamic Marine Component (DMaC) rig.
The FaBTest site is pre-consented to accommodate renewable energy devices which fit within a defined 'Rochdale envelope', greatly reducing the risk, cost and time for developers looking to bring a device to scale tests in sea conditions. The near shore location eases real time monitoring communications, access for inspection and repair, along with proximity to dockyard facilities for fabrication and refit. The devices currently pre-consented are wave energy converters (broadly defined by a range of size constraints), guarded underwater turbines and umbilicals/components. Negotiations are progressing to extend the lease and licence to also accommodate floating wind devices.

RESEARCH & DEVELOPMENT

KEY R&D INSTITUTIONS AND RELEVANT R&D PROJECTS

ENERGY TECHNOLOGIES INSTITUTE (ETI)

Live marine ETI projects: Tidal Energy Converter Phase 2. This is the second phase of the ETI Tidal Energy Converter (TEC) Project. It will design, build and test a multi-turbine foundation structure. Two 1.5 MW turbines will be installed on the structure at the Atlantis owned MeyGen tidal stream array in Pentland Firth, Scotland, increasing

the rated capacity of the tidal array from 6 MW to 9 MW (enough to power 4,500 local homes). Atlantis are developing a patent pending innovative and cost effective turbine foundation design, which nearing completion.

INNOVATE UK

Innovate UK helps organisations and individuals network, share ideas and find project partners. They also offer opportunities to work with international partners, major businesses and government.

Expert knowledge from universities and research organisations can be gained through their Knowledge Transfer Partnerships. In addition to accessing specialist networks through their free online networking platform _connect.

THE OFFSHORE RENEWABLE ENERGY CATAPULT (ORE CATAPULT)

The Offshore Renewable Energy (ORE) Catapult became operational 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.

TECHNOLOGY DEMONSTRATION

PLANNED DEPLOYMENTS

Pre-commercial demonstration tidal array projects:

- The World's first multi-turbine tidal array project, MeyGen Phase 1A (7 MW) in the Pentland Firth in Scotland. This is the first phase of a planned up to 400MW project.
- Pending a 12-month trial of the DeltaStream device in the Ramsey Sound, TEL will join forces with majority shareholder Eco2 to install up to nine DeltaStream machines off St Davids Head in Pembrokeshire to create a 10 MW commercial array.

Pre-commercial wave array projects at wavehub:

- Carnegie Wave Energy Limited, CETO 6 device, 10-15MW wave array project.
- Fortum, testing wave energy converter devices, 10MW wave array project.
- Simply Blue Energy Ltd, Seabased wave energy technology, 10MW wave array project.

Tidal Range schemes:

- Tidal Lagoon Power (TLP), privately funded 320MW Swansea Bay tidal lagoon project.

Demonstration Facility

- Perpetuus Tidal Energy Centre, 30 MW pre-consented commercial tidal array demonstration facility in the Isle of Wight. It is anticipated that the facility will be fully operational around 2018.

OTHER RELEVANT NATIONAL ACTIVITIES

- International Conference on Ocean Energy (ICOE) – 23-25 February 2016, Edinburgh

UNITED STATES OF AMERICA

ALISON LABONTE *U.S. Department of Energy*

INTRODUCTORY NOTE

Marine and hydrokinetic (MHK) technologies capture the energy of waves and currents (e.g., tides, ocean currents, or in-stream river flows). With more than 50% of the U.S. population living within 50 miles of U.S. coastlines, MHK technologies hold significant potential to supply renewable electricity to these consumers, particularly in areas with high costs of electricity. U.S. MHK resource assessments identify a technical resource potential of up to 1,250-1,850 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 cost-effective MHK industry could provide a substantial amount of electricity for the United States due in large part to its unique advantages as a source of energy, such as its vast resource potential, its close proximity to major coastal load centers, and its predictability.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The mission of the U.S. Department of Energy (DOE) Water Power Program is to research, test, evaluate, develop and demonstrate innovative technologies capable of generating renewable, environmentally responsible and cost-effective electricity from water resources. As laid out in the 2015 Quadrennial Technology Review, the strategy has parallel approaches to address two complementary opportunities: (1) near-term deployment in early-adopter markets; and (2) long-term deployment in large, utility-scale markets. The Program's investments along these two parallel approaches fall in the following four major focus areas:

1. Technology Advancement and Demonstration: Provide the support and incentive to incubate revolutionary concepts. Prove technical credibility; catalyse device design evolution; and optimize performance through, for example, application of optimized controls, Power Take-Off, and structure components to double annual energy production and increase availability.

2. Testing Infrastructure and Instrumentation Development: Strengthen MHK device quality and reliability, provide affordable access to facilities for testing, and develop robust instrumentation and sensors.

3. Resource Assessment and Characterization: Classify the U.S. MHK resource, disseminate resource data to stakeholders, and develop numerical modelling tools to predict loading conditions. Quantify and classify environmental conditions to reduce siting risk.

4. Market Acceleration and Deployment: Research environmental risk mitigation, boost investor confidence, and reduce regulatory barriers through examination of effects on aquatic organisms (blade strike, collision, entanglement, noise, electromagnetic fields, species behaviour) and effects on physical systems (hydrodynamic and sediment transport dynamic modelling for both wave and current) are needed.

To facilitate this work, the Water Power Program supports a strong research, development and demonstration (RD&D) project portfolio. The Program also leverages capabilities at DOE national laboratories to spur innovation in promising research areas, identifies cost reduction pathways, and has built coordinated partnerships with other government agencies that are breaking new ground for the industry.

REGULATORY FRAMEWORK

Several key pieces of U.S. federal legislation that would help to advance the MHK industry are currently under consideration:

- The **Marine and Hydrokinetic Renewable Energy Act of 2013** (S. 1419) was introduced in August 2013 and has been recommended by the Senate Energy and Natural Resources Committee for full consideration by the Senate. Sponsored by Senator Ron Wyden and cosponsored by Senators Lisa Murkowski and Angus King, this bill would promote research, development, and demonstration of MHK renewable energy technologies.
- The **Renewable Electricity Standard Act of 2013** (S. 1595) and the **American Renewable Energy and Efficiency Act** (S. 1627), both pending in the Senate Energy and Natural Resources Committee, would each create a renewable electricity standard that would apply to all renewable energy sources.
- The **Climate Protection Act of 2013** (S. 332) would enable the Environmental Protection Agency to establish a 'Sustainable Technologies Finance Program' that would alleviate cost burdens for ocean, tidal, or hydropower energy projects through loans, credit instruments, and loan guarantees. This bill is sponsored by Senator Bernie Sanders and is under consideration by the Committee on Environment and Public Works.
- The **Prioritizing Energy Efficient Renewables Act of 2013** (H.R. 2539) would permanently extend the Renewable Energy Production Tax Credit for wind, geothermal, hydro, and marine power. It would also eliminate the tax credit for intangible drilling costs, the domestic manufacturing tax credit for oil and gas, as well as the percentage depletion credit for oil and gas wells. Sponsored by Representative Jan Schakowsky and 22 other cosponsors, this bill is currently under consideration by the House Committee on Ways and Means.
- The **Advancing Offshore Wind Production Act** (H.R. 1398), sponsored by Representative Rob Wittman, would set a 30-day timeline for the Secretary of the Interior to act on permits for all weather testing and monitoring projects in the U.S. Outer Continental Shelf. This bill includes a provision that would apply this timeline to tidal and ocean current energy projects. This bill has been referred to the House Subcommittee on Energy and Mineral Resources.

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 PTC, which provides a 1.1 cents per kilowatt- hour (kWh) tax credit for MHK technologies, has recently been extended through 2016 for projects that are at least 150 kW in nameplate capacity. The ITC allows tidal energy projects to opt for a tax credit equal to 10% of capital expenditures in lieu of the PTC. There is no Investment Tax Credit for MHK technologies other than tidal.

At the state level, MHK technologies are an eligible energy resource under 20 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 PROGRAMS

Because MHK energy is an early stage market and there are currently limited incentives for investment, the Water Power Program has a clear role in expediting the development and deployment of innovative MHK technologies. The Program focuses on investing in technologies with a credible potential for lowering the levelized cost of energy (LCOE) below the local hurdle price at which MHK can compete with other regional generation sources. In the near term, the focus is on early-adopter high-hurdle rate markets and in the longer-term the focus is on competitiveness at utility scale in regional markets. The Program makes investments that mitigate risks, support key technology innovations, and assist the private sector in creating a robust U.S. MHK industry by providing funding and technical assistance. The completion of national assessments of U.S. wave, tidal, ocean current, river in-stream, and ocean thermal energy resources has resulted in an emphasis in technology development efforts of the abundant national wave energy resource.

The Water Power Program's Fiscal Year (FY) 2015 annual budget for MHK RD&D was maintained at $41.3 million from FY 2014. Most of the funding in FY 2015 was directed toward Focus Area 1: Technology Advancement and Demonstration.

Through competitive funding solicitations, or Funding Opportunity Announcements (FOAs), the Water Power 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 technologies.

In FY 2015, the Water Power Program allocated $17.9

million of the $41.3 million to new FOAs for MHK RD&D projects that aim to address key technical and market barriers to 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 System Performance Advancement II: $7.4 million to spur innovation of next-generation water power component technologies designed for manufacturability and built specifically for MHK systems.
- Durability and Survivability: $10.5 million to support the design and operation of innovative MHK systems through survivability and reliability-related improvements.

MHK System Performance Advancement: In August 2015, four entities were selected to receive a total of $7.4 million to address technical challenges in three areas: advanced controls, crosscutting Power Take-Off. Re Vision Consulting, LLC, will develop an optimal control system that predicts ocean conditions and adjusts device settings accordingly to optimize power production for three different wave energy converter (WEC) devices. Virginia Tech will develop and test a novel mechanical solution for converting from alternating current to direct current power by transforming the back-and-forth wave movement into a single-directional movement to more efficiently capture wave energy. Dehlsen Associates, LLC, will develop a linear generator capable of supplying a WEC device with power to implement advanced controls. Pennsylvania State University will develop a low-cost, single-piece, three-blade composite turbine with integrated "health management" technology that uses diagnostic and predictive technologies to evaluate the health of mechanical and electrical systems during operation.

Durability and Survivability: In December 2015, six organizations were selected to receive a total of $10.5 million to improve the survivability characteristics and reduce uncertainty regarding installation, operations, and maintenance of MHK systems operating in potentially harsh marine conditions, thus extending their lifespans and ultimately leading to a reduction in the cost of MHK-derived energy. Dehlsen Associates, LLC, is developing a WEC comprised of multiple pods that use common components to achieve economies of scale and improve its survivability characteristics, thus significantly reducing the cost of energy derived from the WEC. M3 Wave LLC will develop modelling tools to explore ways to minimize effects of sediment transport, such as water erosion, displacement, and tilting of their WEC that sits on the ocean floor and captures energy from the pressure waves beneath ocean waves. Oscilla Power, Inc. is developing a WEC consisting of a surface float that is tethered to a base suspended in the water, which aims to optimize storm-survival configurations, thus decreasing the loads the device experiences during extreme conditions and lowering the resulting cost of energy. Columbia Power Technologies, Inc. will develop and deploy a streamlined, cost-effective installation and recovery process that includes design updates and process improvements related to IO&M. Igiugig Village Council will work with Ocean Renewable Power Company to develop a river turbine system that will demonstrate IO&M design improvements to simplify maintenance and make system components more durable during operations in southwestern Alaska. Verdant Power, Inc. will complete their TriFrame foundation, which optimizes turbine spacing and support structures to allow for cost-effective IO&M.

Under DOE Small Business Innovation Research and Technology Transfer (SBIR/STTR) program, DOE funded four Phase I projects in 2015 at $150,000 each to help small businesses develop prognostic and health monitoring systems for MHK devices. The period of performance for these projects is nine months, after which the projects will be eligible to compete for up to $1 million in Phase II funding. Commercial-scale MHK energy converters are large, often highly complex devices operating in a harsh marine environment, and servicing these devices at sea is a difficult and costly operation. Advanced prognostic and health monitoring systems help to anticipate and identify relevant changes to device health, minimize the unscheduled maintenance and failure frequency, and decrease LCOE through reduced maintenance costs and increased device availability.

MARINE SPATIAL PLANNING POLICY

In addition to the Water Power Program's work, the National Ocean Council continues to promote regional ocean planning efforts in the United States, notably with a group of regional planning bodies that coordinate ocean activities and develop marine spatial plans for their regions. Similarly, the Bureau of Ocean Energy Management within the U.S. Department of the Interior has established a series of state task forces to lead planning efforts for marine renewable energy in a number of states with MHK resources, including Oregon and Hawaii.

PERMITTING AND LICENSING PROCESS FOR OCEAN ENERGY PROJECTS

While significant progress has been made to expedite the permitting process for MHK technologies in the United States, especially for pilot scale and research projects, the amount of time, finances, and other resources required to navigate the permitting process remains a challenge for many MHK projects. To help ensure that the regulatory community has access to the most recent, amalgamated information regarding MHK systems and environmental research, the Water Power Program sponsored a MHK regulator training workshop in May 2015.

TEST SITES

Testing infrastructure and instrumentation development represents one of the four major focus areas for the Water Power Program. Test facilities are intended to offer a wide range of testing services that address both technical and nontechnical barriers of MHK systems. Prototype testing is essential to advance existing wave technologies, validating performance against analytic models, and demonstrating compliance with applicable design standards. Testing mitigates the technical and financial risk of developing and deploying mass-produced wave energy devices, plants, technologies, and related products. By spearheading the development of a 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 of developing, permitting and installing their own test facility. As a result, superior 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 open-ocean wave energy test site facility located at Marine Corps Base Hawaii. The existing facility consists of infrastructure to support offshore testing of a point absorber or oscillating water column device with up to a three-point mooring configuration. The Navy previously operated a grid-connected test berth at a depth of 30 meters, however in 2015, construction was completed for two additional grid-connected test berths at the at 60-meter and 80-meter depths for 100 kW to 1 MW WECs.

National Marine Renewable Energy Centers (NMRECs): In 2015, the Water Power Program continued to support the NMRECs, which provide domestic expertise in MHK device testing and the evaluation of environmental performance data, ultimately providing the necessary level of confidence to enable the private financing of commercial generation plants.

Pacific Marine Energy Center (PMEC) – Wave and River Test Facility: 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 will encompass the range of test facilities available to the marine energy industry. 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. The Lake Washington site is operated by the University of Washington in Seattle, and tested Oscilla Power's wave energy technology in 2013. In 2014, NNMREC was joined by University of Alaska Fairbanks, and PMEC now includes the Tanana River Hydrokinetic Test Site in Alaska. Oceana Energy Company tested their turbine technology at the Tanana River site in 2014.

Pacific Marine Energy Center - South Energy Test Site (PMEC-SETS) and the California Wave Energy Test Center (CalWave) – Wave and Tidal Test Facilities under development: In 2015, with $1.5 million in additional funding from the Water Power Program, 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. The Program will use the results of these projects for planning and budgeting of a domestic wave energy test facility. PMEC-SETS is located off the coast of Oregon, and has submitted preliminary permitting documents. Following construction, PMEC-SETS would serve as the utility-scale, grid-connected wave energy test facility for evaluating WEC device performance, environmental interactions, and survivability. CalWave has investigated and characterized several potential locations for a wave energy site offshore of Vandenberg Air Force Base in southern California. Researchers will continue preliminary design and cost estimates for a selected location and begin the permitting process in 2016.

Southeast National Marine Renewable Energy Center (SNMREC) – Ocean Current Test Facility: SNMREC 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 2014, SNMREC signed a five-year lease agreement with the U.S. Department of the Interior Bureau of Ocean Energy Management, and expects to test small scale commercial

ocean current turbines during 2016. During 2015, SNMREC performed sea floor surveys for the offshore test berth lease and installed coastal radar to better characterize the Gulf Stream for commercial power production.

Hawaii National Marine Renewable Energy Center (HINMREC) – Wave and Ocean Thermal Energy Conversion (OTEC) Test Facility: 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 will support the Navy in testing WEC devices at the Navy's two new test berths at WETS at Kaneohe Bay, Hawaii. HINMREC will assess the power performance of WEC devices, including but not limited to Ocean Energy USA's and Northwest Energy Innovations' FOA R&D projects. HINMREC will also determine acoustic and electromagnetic field outputs at the WETS, which will contribute to the environmental impact assessment of WEC devices and other MHK technologies.

RESEARCH & DEVELOPMENT

ABOUT NATIONAL LABORATORIES

In addition to NMRECs, DOE's national laboratories possess unique instruments and facilities and address large scale, complex R&D challenges with an approach that emphasizes translating basic science to innovation. The Water Power Program partners with several of these important R&D institutions to support R&D in MHK technologies.

Sandia National Laboratories (SNL): Through a partnership 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, code development, array optimization, and extreme events simulation
- Designs and tests of tidal turbines and development requirements for deep tank testing
- Advanced materials development, such as novel coatings and composites
- Wave resource assessment, environmental characterization, and classification
- Measurement and modelling of tidal and 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 research supports the Water Power Program's efforts to research, test, evaluate, develop, and demonstrate deployment of innovative water power technologies. NREL supports development of market-relevant scientific and technical knowledge, research and testing, and addressing environmental impacts. Specifically, NREL supports the Program through:

- Computational modelling and analysis of wave and tidal devices in operational and extreme conditions
- Industry project support and needs assessment
- Instrumentation system development testing
- Laboratory, electrical, grid, and mechanical testing
- Standards development and certification support
- Wave and current resource assessment and characterization
- Stakeholder training, education, and outreach

Pacific Northwest National Laboratory (PNNL): PNNL supports the Water Power Program through research; engineering; information aggregation and dissemination; resource assessment, characterization, and forecasting; and 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 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

Oak Ridge National Laboratory (ORNL): ORNL is involved in a number of R&D activities supporting the Water Power Program's mission. These activities and products help all stakeholders understand and resolve the environmental effects of MHK technologies and help developers advance MHK technologies to commercialization. ORNL scientists are currently reporting on laboratory and field experiments that evaluated the effects of noise and electromagnetic fields on marine organisms, and are conducting hydroacoustic analysis of fish interactions with turbines.

2015 MHK R&D HIGHLIGHTS

Wave Energy Prize: With $6.5 million awarded to Ricardo, Inc. as the competition's administrator, the DOE-funded Wave Energy Prize had 92 eligible teams registered to compete for a prize purse totalling more than $2 million. The judging panel narrowed the 92 registered teams down and the 20 qualified teams were announced on 14 August 2015. Seventeen of these 20 qualified teams currently remain, and teams are testing 1/50 scale WECs over winter 2015/2016 for their potential to achieve DOE's goal of doubling the state-of-the-art energy captured from ocean waves per unit structural cost. The testing will occur at five universities across the country: the University of Michigan, University of Maine, University of Iowa, Oregon State University, and Stevens Institute of Technology. NREL and Sandia National Laboratories (SNL) are providing technical expertise in preparing testing plans, numerical modelling templates, and methodology for evaluating against performance metrics. On 1 March 2016, up to 10 finalists will be selected to test their 1/20scale model WECs in the nation's most advanced wave-making facility—the Naval Surface Warfare Center's Manoeuvring and Seakeeping Basin at Carderock, Maryland.

Instrumentation Database and Community of Practice: Sharing information on MHK instrumentation and lessons learned from laboratory testing and field deployments will help the emerging MHK community achieve greater success in technology development. DOE has developed a comprehensive and open instrumentation database and community of practice as a set of online tools for the international MHK community to contribute and draw information.

This database will help users identify and select instruments and sensors that best satisfy measurement needs based on testing objectives (e.g. power performance certification and numerical model validation) and associated measurement requirements. The database is also intended to allow users to document the performance of instruments in the field and lessons learned so that their experience can directly benefit the online MHK community. Users are also able to record instrument configurations and best practices in a "community of practice." The community of practice is a forum for developers, users, and stakeholders to engage in constructive dialog and exchange ideas, as well as lessons learned across a broad range of testing and instrumentation topics. Through this effort, limitations in measurement capabilities and functionality can be more easily identified and will help the community understand gaps in measurement technology.

In 2015, DOE developed the framework for the MHK instrumentation and sensor database and the community of practice and launched the database on a public website. The database has been initially seeded with a representative set of instruments and sensors used for resource assessment.

Advanced Design Tools: In 2015, the DOE Water Power Program and national laboratories performed research on wave and current energy devices with the objectives of improving performance, reliability, and survivability, while lowering the cost of energy. NREL and SNL worked on the following projects in 2015 to provide open-source simulation tools, develop extreme condition design methodologies, and advance control strategies:

- The Wave Energy Converter Simulator project developed and released an open-source design and analysis code (WEC-Sim) and performed experimental wave tank tests to develop validation data sets. Code development and experiments are continuing in 2016 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 analyse the performance of WECs in extreme and survivability conditions.

- SNL and NREL worked to advance WEC control strategies through two projects.
- SNL prepared for a comprehensive set of wave tank tests that will characterize the performance of several advanced control strategies using a point absorber WEC design.
- 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. In 2016, SNL and NREL will continue to explore advanced control strategies that have the potential to significantly improve the performance of wave energy devices.

Resource Assessment and Characterization Meeting: In November 2015, the DOE Water Power Program hosted a meeting with key stakeholders in Washington, D.C., to better integrate private industry and universities with the MHK resource assessment and characterization activities at DOE and its national laboratories. The main purpose of the meeting was to provide an in-person opportunity to meet and hear directly from industry and academia stakeholders. The feedback received through this open dialogue will help guide future MHK resource assessment and characterization work at DOE. Information about DOE's past and current MHK resource assessment and characterization portfolio was shared, along with plans for future research. After hosting this open forum, industry and academia stakeholders expressed their desire for regular, future engagement to discuss DOE's MHK resource assessment and characterization portfolio with the Water Power Program. Moving forward, a resource assessment and characterization subcommittee within the Marine Energy Council (MEC) will have regular meetings with DOE to provide guidance on current work and future plans for the DOE MHK resource assessment and characterization portfolio. MEC was formed by the National Hydropower Association to unite the marine energy community in order to better provide input on how to best leverage Water Power Program research and development investments to further the marine energy sector. Stakeholders also encouraged DOE to engage with the International Electrotechnical Commission Technical Committee 114 (IEC TC114) for Marine Energy for feedback on current and future MHK resource assessment and characterization work.

LCOE Modelling: To normalize competing claims of LCOE, the Water Power Program and national laboratory partners have developed, for the Program's own use, a standardized cost and performance data reporting process to facilitate uniform calculation of LCOE from MHK device developers. This standardization framework is a working version in what is anticipated to be an iterative process that involves industry and the broader Water Power Program stakeholder community. In 2015 the Water Power Program and industry stakeholders worked together to define cost reduction and technology development pathways aimed to further develop MHK technologies. These efforts will continue to be refined as technology is developed and insight is gained across the Program.
The LCOE reporting process references a generalized Cost Breakdown Structure (CBS) for MHK projects that is being developed by the Water Power Program and NREL. This CBS is a hierarchical structure designed to facilitate the collection and organization of lifecycle costs of any type of MHK project, including WECs and current energy converters. At a high level, the categories in the CBS will be applicable to all projects; at a detailed level, however, the CBS includes many cost categories that pertain to one project but not others.

Reliability Framework: To help reduce the risks of industry failures and advance the development of current and new technologies at a lower cost and faster pace, the Water Power Program and NREL have developed an MHK technology reliability and survivability risk assessment framework. This framework provides a risk management methodology to identify and reduce risks during all stages of technology development, particularly prior to demonstration activities. The framework was released in September 2015.

MHK Data Repository (MHKDR): Working with NREL, the Water Power Program launched the MHKDR website on 31 March 2015. This repository houses all data collected using funds from the Water Power Program, serving as a data-sharing platform to help store and disseminate open-source data relevant to the design and development of marine energy technologies. Transparency and open data are extremely important to accelerate technology development in order to avoid funding the same technology evolution by several different companies, and also to attract new players from related offshore and engineering sectors. The MHKDR provides an easy method for uploading data in a secure environment in order to help with the reporting requirements of national labs and industry awardees, as well as to make this information easily searchable and of value to the public. Awardees who received U.S. public funding through financial assistance mechanisms are able to keep their data proprietary for a period of up to five

years, after which it is to be made available to the public. In 2015, eight content models were developed to help structure the data submitted to the MHKDR, and a training session and live demonstration were posted.

NNMREC's Advanced Laboratory and Field Arrays Project (ALFA): NNMREC is a multi-institution entity with a diverse funding base that focuses 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 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

Environmental R&D: In 2015, five projects got underway to improve existing or develop new environmental monitoring technologies, which will help address the technological limitations associated with environmental monitoring of MHK devices. These projects focus 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 to monitor MHK devices more efficiently. The Water Power Program had awarded $2.75 million in 2014 to support these projects.

Also in 2015, nine projects that focused on advancing the understanding of potential environmental effects from the deployment and operation of MHK devices made excellent progress, and many are in the process of finishing up. The projects include 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 that electromagnetic fields may have on marine species. The Water Power Program awarded $2.4 million in 2013 to support these projects.

TECHNOLOGY DEMONSTRATION

OPERATIONAL PROJECTS

Northwest Energy Innovations: With support from DOE and the U.S. Navy, a prototype wave energy device advanced successfully from initial concept to grid-connected, open-sea pilot testing in June 2015. The device, called Azura, was launched and installed in a 30-meter test berth at the Navy's WETS in Kaneohe Bay, on the island of Oahu, Hawaii. NWEI designed the Azura in a unique way to extract power from both the vertical and horizontal motions of waves to maximize energy capture. This pilot testing is now giving U.S. researchers the opportunity to monitor and evaluate the performance of the third-party-verified and grid-

connected device in the open-ocean for the duration of one year. The primary objectives of this test are to use the data collected to optimize energy capture, and to validate and refine existing cost and performance models.

Ocean Renewable Power Company (ORPC): In July 2015, ORPC deployed its RivGen® turbine in the Kvichak River, located at the Igiugig village in Alaska. The RivGen® Power System demonstration project provided power to Igiugig. Connecting the small community to the grid and decreasing the use of high-cost diesel fuel for electric power generation helps lower electricity costs for consumers since all fuel must either be barged or flown in to the rural village, and that cost is passed on to rate payers. This project was successfully decommissioned after two months of operation, and numerical models and deployment data are being analysed and validated to evaluate the improvements from implementing advanced control systems. ORPC's advanced control systems are being developed in collaboration with the University of Washington, Maine Technology Institute, and NREL with support from the DOE Water Power Program.

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 the half scale device is currently being tested at the 30m berth at WETS. With funding from the DOE Water Power 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 deployment in 2017.

Resolute Marine Energy: The Water Power Program is supporting Resolute Marine Energy to develop an intelligent feedback control algorithm for their next-generation device, SurgeWEC™. The control system will be validated in Resolute's development centre on a full scale SurgeWEC™ and, upon completion, will be integrated into Resolute's project planned for deployment off the coast of Camp Rilea, Oregon.

Fred Olsen: Fred Olsen's BOLT Lifesaver WEC device will be deployed at WETS early next year with the support of U.S. Navy funding. The BOLT Lifesaver in its current configuration features three independently operating Power Take-Off units, an all-electric power conversion system, and a patented drivetrain. Its hull design provides buoyancy and water displacement and has a low vertical profile, which reduces the impact of sea forces during more aggressive sea states. BOLT Lifesaver has on-board energy storage that enables autonomous and continuous operation through varying sea states.

Columbia Power Technologies: Columbia Power Technologies will conduct an open water demonstration of a utility scale StingRAY at WETS in 2016 or 2017. With funding from the Water Power Program, the StingRAY has innovated a direct-drive permanent magnet generator for Power Take-Off which reduces the number of moving parts, compared to gearboxes, integrated with a composite hull structure for the generator's "nacelle." The composite structure helps to increase the strength and longevity of the device. The deployment at WETS, supported by the U.S. Navy, will include StingRAY utility scale design and certification, performance and efficiency validation, and design and testing of the structural components.

OTHER RELEVANT NATIONAL ACTIVITIES

In 2015, the Marine Energy Council (the U.S. industry association for MHK) and DOE's Water Power Program will once again hold the International Marine Energy Conference and the Marine Energy Technology Symposium. These events are being held this year at the Capitol Hilton Hotel in Washington, D.C., on 25-27April 2016 in conjunction with the National Hydropower Association (NHA) Annual Conference. Holding these three events together provides the invaluable opportunity for public and private industry stakeholders and the R&D community to come together to advance the interests of the U.S. marine energy industry. More information on all three events can be found on the NHA annual conference website.

Numerous experts from National Labs, industry, and academia participate in IEC TC 114, both administratively and on project teams to support the development process and ensure that U.S. input is considered as international standards for the MHK industry are developed. The development of standards will facilitate more rapid and reliable deployment of MHK devices. In 2015, the U.S. Technical Advisory Group staffed 20 IEC-related meetings around the globe and contributed to the publication of three technical specifications covering mooring systems, wave energy resource assessment and characterization, and tidal energy resource assessment and characterization. Publishing these as specifications is the first step toward these guidelines becoming published as international standards to be used by the MHK industry and certifying bodies, which will help secure investments in marine energy projects.

06

APPENDICES

Appendix 1

TECHNOLOGY COLLABORATION PROGRAMMES

The International Energy Agency provides support for international collaboration on energy technology research, development, deployment and information dissemination. These energy technology collaboration programmes (formally known as Implementing Agreements or 'IAs') function within a framework created by the IEA - *the International Framework for International Energy Technology Collabora*tion - in support of energy security, economic growth, environmental protection and engagement worldwide.

The experts participating in the activities of the TCPs represent public and private sector entities worldwide. Together, these experts share knowledge – and resources – to advance energy technologies.

This IEA technology collaboration programme is open to IEA member and non-member countries. Typically, participants are:

- Governmental or energy technology entities representing governments,
- Research institutes and universities,
- Energy technology companies.

Each Technology Collaboration Programme has a unique scope and range of activities. There are currently 40 IAs working in the following areas:

- Efficient end-use technologies (buildings, electricity, industry, transport);
- Fossil fuels (greenhouse-gas mitigation, supply, transformation);
- Renewable energies and hydrogen (technologies and deployment) and fusion power (international experiments); and
- Cross-cutting issues (information exchange, modelling, technology transfer).

Renewable energy technologies provide clean, flexible, standalone or grid-connected electricity and heating or cooling. Ten IAs deal with renewable energy technologies:

- Bioenergy
- Geothermal
- Hydrogen
- Hydropower
- Ocean Energy Systems
- Photovoltaic Power Systems
- Renewable Energy Technology Deployment
- Solar Heating and Cooling
- SolarPACES
- Wind Energy Systems

Further information is available at: www.iea.org/tcp

Appendix 2

MEMBERSHIP OF THE EXECUTIVE COMMITTEE

CABINET

CHAIRMAN
Mr. Jose 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 – Offshore Renewables
Portugal

DELEGATES

COUNTRY	DELEGATE	ALTERNATE
Belgium	Dr. Ludovic Mouffe Federal Public Service Economy	Prof. Julien de Roeck Ghent University
Canada	Mrs. Tracey Kutney 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
Germany	Mr. Ullrich Bruchmann Federal Ministry for the Environment, Nature Conservation and Nuclear Safety	Mr. Jochen Bard Fraunhofer Institute for Wind Energy and Energy System Technology IWES
Ireland	Mr. Declan Meally Sustainable Energy authority of Ireland	Prof. Tony Lewis Hydraulics and Maritime Research Centre, University College Cork
Italy	Mr. Luca Benedetti (Delegate) 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	Dr. Sergio Alcocer Instituto de Ingeniería UNAM	Mr. Carlos Ortiz Gomez General Directorate of Information and Energies Studies
Monaco	HE Bernard Fautrier Government of the Principality of Monaco	
The Netherlands	Mr. H.W. Boomsma Ministry of Economic Affairs	Mr. H.P.E.M. Reijnders Netherlands Entreprise Agency
New Zealand	Dr Craig Stevens National Institute for Water and Atmospheric Research (NIWA)	Mr. Nick Eldred 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
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 MEETINGS

MEETING	DATE	PLACE	
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

PLANNED MEETINGS

MEETING	DATE	PLACE	
30	9-10 May 2016	Gothenburg	SWEDEN
31	October 2016		SINGAPORE

Appendix 4

COMPLETED ANNEX 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

Appendix 5

TERMINOLOGY FOR OES

TERM	DEFINITION
ANNEX	An Addendum to a Technology Collaboration Program (TCP) and an integral part thereof, which sets forth the manner, including the financial undertakings and other means of support, by which the activities (sometimes called Tasks) of the Annex will be implemented by the Participants.
CERT	Committee on Energy Research and Technology is one of the IEA Standing Committees. Comprised of representatives from each IEA Member country and supported by the Secretariat, the CERT formulates and supervises the execution of the IEA's R&D programme, including national programme reviews, technology reviews, studies on strategic planning and oversees the IAs. The CERT is supported by four Working Parties on Renewable Energy, End Use Efficiency, Fossil Fuels, and Fusion Power.
COMMON FUND	The fund established by the Executive Committee into which the financial contributions of the Participants are placed.
CONTRACTING PARTY (CP)	Signatory of a Technology Collaboartion Programme (TCP).
EXECUTIVE COMMITTEE (EXCO)	The body, comprising representatives of all the Participants in a TCP, which supervises the work of the IA and is the decision making body of the TCP.
EXCO REPRESENTATIVE	The individual designated by each Participant to be the Participant's representative on the Executive Committee.
OPERATING AGENT (OA)	The legal entity designated in the TCP text, or by the ExCo, or by the Participants in an Annex, to manage part or all of the Programme of Work of a TCP and/or of its Annexes. The overall plan of activities determined by the Executive Committee to be implemented under the TCP.
TECHNOLOGY COLLABORATION PROGRAMME (TCP)	The contractual relationship established by at least two IEA Member countries and approved by the Governing Board to carry out programmes and projects on energy technology research, development and deployment.
WORKING PARTY (WP)	One of the current Working Parties mandated by the CERT to carry out specified work in energy technology and to initiate, evaluate and review TCPs in its special field. At present, the Working Parties are: the Working Party on Energy End Use Technologies (EUWP); the Working Party on Fossil Fuels (WPFF); the Working Party on Renewable Energy Technologies (REWP); and the Fusion Power Coordinating Committee (FPCC).

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