Energy Technology Network

Annual Report 2010
Implementing Agreement on Ocean Energy Systems

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Implementing Agreement on Ocean Energy Systems

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Chairman's Message

Dr. John Huckerby
Aotearoa Wave and Tidal Energy Association
OES-IA Chairman 2009-2012

Welcome to the 2010 Annual Report of the Ocean Energy Systems Implementing Agreement (OES-IA) of the International Energy Agency (IEA). This provides an overview of the activities and achievements of the Executive Committee of the OES-IA, three current Annexes (work programmes) and of its member countries.

2010 was an important year for the Executive as it prepared to submit a new 5-year Strategic Plan to the IEA to secure a third 5-year mandate (in October 2011). A key component of this Plan will be a Communication Plan, which will raise the profile of OES-IA and of its efforts to "*to realize cost-competitive, environmentally sound ocean energy on a sustainable basis to provide a significant contribution to meeting future energy demands*". Its new mandate will be to make it "***the authoritative voice on ocean energy***". To realize this new direction, the OES-IA commissioned a document called an "***International Vision for Ocean Energy***", which will be published later in 2011. This will set out the current status, progress, opportunities for and barriers to uptake of ocean energy.

Membership of OES-IA has continued to grow with the Republics of Korea and South Africa joining in 2010. The Executive has welcomed observers from India, China and Indonesia to its meetings this year. Invitations to join have been sent to France, Brazil, the Netherlands, Chile, Indonesia China, India and Finland.

The work programmes within our Annexes have been productive this year: four reports have been published (see www.iea-oceans.org). Annex II (on open-sea testing of prototype devices) has been completed this year and the final report from Annex III (integration of ocean energy plants into distribution and transmission grids) is due for publication early in 2011. Annex IV (on assessment of environmental effects and monitoring efforts) has made good progress with a well-attended and productive workshop in Dublin in September 2010. Three new annex proposals are under consideration.

The following Executive Summary gives a wide-ranging outline of activities and achievements in OES-IA member countries but I would like to focus on three trends. Firstly, **there is no substitute for getting devices in the water**. The country summaries at the end of this report detail an increasing number of devices being tested for longer at scale and in open-sea conditions. Some have reported problems but such problems are inevitable and may lead to accelerated development in due course.

Secondly, **the wider supply chain is becoming involved**. Whilst electrical utility investment in device developments has continued during 2010, the focus has broadened to infrastructure requirements: deployment equipment, moorings, electrical connections and materials. Testing centres continue to proliferate internationally, encouraging collaborative R&D between developers and their supply chains.

Thirdly, this year saw **consolidation between offshore wind and marine energy projects**. This was perhaps best exemplified at the International Conference on Ocean Energy, which was held in Bilbao in October 2010. Given the changed economic conditions since 2008, marine energy projects must look for synergies with other offshore developments. Whilst it is common for marine energy projects to be described as "commercial", it is questionable whether any has achieved that status yet: no devices are being mass-produced.

Investment funding has become more difficult to secure in the last few years, so it is more important that marine energy industry players co-operate. In Europe there is an increasing number of research initiatives, some with overlapping objectives. Developers, researchers, policymakers and funding bodies must communicate to ensure coherent development of the industry. The increasing introduction of feed-in tariffs demonstrates a maturation of funding away from R&D capital grants to market-led development.

OES-IA aims to facilitate that co-operation by becoming a clearing house for authoritative information on the development of ocean energy, whether it be technical, environmental or social impact data. In October we published our first Bulletin, available on the website, to replace the old format newsletter and we will be increasing our presence at international ocean energy conferences.

We must ensure that the promise of ocean energy as a non-polluting, sustainable and renewable energy resource is evident and realized around the world.

Executive Summary

Introduction

This 2010 Annual Report reviews the progress of activities of the Implementing Agreement on Ocean Energy Systems (OES-IA) of the International Energy Agency (IEA) during the year 2010. The OES-IA operates within a framework created by the IEA.

"The International Energy Agency (IEA) was established as an autonomous body within the Organisation for Economic Co-operation and Development (OECD) in 1974 to implement an international energy programme and act as a policy advisor to countries on energy, including renewable energy. Presently the IEA has 28 member countries. The 42 multilateral technology initiatives (Implementing Agreements) supported by the IEA are a flexible and effective framework for IEA member and non-member countries, businesses, industries, international organizations and non-government organisations to research breakthrough technologies, to fill existing research gaps, to build pilot plants, to carry out deployment or demonstration programmes – in short to encourage technology-related activities that support energy security, economic growth and environmental protection."

The Implementing Agreement on Ocean Energy Systems (OES-IA) was initiated by three countries in 2001. As of December 2010, 18 countries are members of the OES-IA: 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 and South Africa, ordered by sequence of joining the Agreement. The last two, the Republics of Korea and South Africa, joined in 2010. Further countries have been invited and are expected to join in the next years, including Finland, France, Brazil, India, the Netherlands, China, Chile and Indonesia.

This annual report presents the activities of the OES-IA during 2010. Task 2 – Development of Recommended Practices for Testing and Evaluating Ocean Energy Systems, terminated in 2009 and in early 2010 a set of reports were published in the website covering i) generic and site related wave and tidal data, ii) development and evaluation protocol for ocean energy systems and iii) guidelines for open sea testing and evaluation of ocean energy systems.

The work programme during the year focused on 3 Tasks:

- Task 1 – Review, Exchange and Dissemination of Information on Ocean Energy Systems
- Task 3 – Integration of Ocean Energy Plants into Distribution and Transmission Electrical Grids
- Task 4 – Assessment of Environmental Effects and Monitoring Efforts for Ocean Wave, Tidal and Current Energy Systems

Chapter 1 of the present report describes the basic organization, membership and activities of the OES-IA during 2010. Chapter 2 presents the progress report of the tasks that are currently active, as well as the concluded Task 2.

Chapter 3 presents the international situation on ocean energy: each Executive Committee member provides an overview of national activities focusing on the ocean energy policy, research, development and technology demonstrations during the year.

Chapter 4 presents three articles on specific topics of ocean energy prepared by invited experts, following an initiative of the ExCo that started in 2008. In the 2008 Annual Report, the theme was the current status of ocean energy technologies; in 2009 the theme was key technical and non-technical challenges that ocean energy faces and actions that are and could be taken to promote and accelerate deployment of ocean energy; **in this report the theme is "Key facilitators for ocean energy".**

Political incentives to push the ocean energy market

Political initiatives highlighted in 2010 include:

UK: The announcement of successful bidders for wave and tidal energy leases in UK waters for a proposed total installed power of 1.6 GW for 2020; the preparation of an offshore renewable energy strategic action plan 2009-2020 for Northern Ireland waters, including a target of 300 MW of tidal stream by 2020; the completion of the Severn tidal power feasibility study in the UK, concluding that is not the right time to develop the project.

Ireland: The governmental allocation of a financial package for ocean energy administered by a new Ocean Energy Development Unit (OEDU) based within the Sustainable Energy Authority of Ireland (SEAI), covering support for device developers, enhancement of test facilities, and development of grid-connected test facilities.

Portugal: Signature of the contract between the government and the management body, REN (National Energy Networks) for the development of the Wave Energy Pilot Zone and the creation of the dedicated REN subsidiary, ENONDAS.

Spain: The official announcement of ocean power targets by the Spanish Government: 100 MW of installed power by 2020 while the first 10 MW are expected in 2016.

Norway: Set up of new legislation for renewable offshore energy production with an efficient licensing process.

Italy: The interest of the government in promoting wave and tidal energy, through a Green Certificates System as support scheme, equivalent to a higher feed-in tariff of € 0.34 /kWh.

Germany: Preparation of the "National Master Plan Maritime Technologies" by the government to support the development of the maritime technology industry in the coming years, anticipating that ocean energy will play a prominent role in the plan.

Canada: Federal Government commitment of funding to marine renewable energy research; Provincial governmental initiatives promoting marine energy, such the British Columbia's Clean Energy Act announced in mid-2010, to commit to developing support mechanisms (i.e., feed-in tariff) for emerging technologies, such as ocean energy.

USA: A new national ocean policy launched in July 2010 implemented through the newly formed National Ocean Council; substantial government support established to accelerate the technological and commercial readiness of ocean technologies.

New Zealand: Publication of the draft National Energy Strategy for consultation in July 2010, with a particular focus on innovation and commitment to a 4th round of Marine Energy Deployment Fund (MEDF); formation of a syndicate to develop a testing centre for wave and tidal energy developments.

Korea: Significant increase of public and private funding for ocean energy R&D amounting to € 13 million in 2010 and initiation of a first major project on ocean thermal energy conversion by the government.

Open sea testing facilities

The development of sea testing facilities for different stages of the development process is seen as a typically valuable measure at governmental level. In addition to direct support funding schemes, such as feed-in tariffs, providing 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.

Several initiatives of this type were reported by the member countries during 2010. Work is under way on several marine energy infrastructures. The Wave Hub grid-connected offshore facility for the large scale testing of technologies was deployed in South West England in September 2010, the first infrastructure to be announced for pre-commercial array deployment, consisting of a connector and distributor on the seabed with an initial maximum capacity of 20 MW. Further, the *European Marine Energy Centre* (EMEC), the first full-scale grid-connected research centre for both wave and tidal prototypes based on Orkney islands (Scotland), has been very active and expanded the number of berths in 2010.

In Denmark, two new testing facilities became operational in 2010: the *Danish test site for Wave Energy Conversion* (DanWEC) in Hanstholm and the Lindø

Offshore Renewables Center (LORC) for offshore renewables. The Danish Nissum Bredning site for testing 1:4 wave energy technologies continued to be active.

The physical implementation of the Portuguese Pilot Zone for demonstration and commercial projects, licensed in 2008 with a maximum capacity of 250 MW is now closer to realisation, after the creation of the company ENONDAS in 2010 to initiate and manage the Pilot Zone.

In Spain, bimep (*Biscay Marine Energy Platform*), promoted by EVE for full-scale prototype testing and demonstration with a capacity of 20 MW, is waiting for permits but work has advanced.

Runde Environmental Centre (REC) on the island of Runde, off the Norwegian west coast, has initiated plans to establish a test site, following the field tests of the Seabased "Maren" wave power project in 2009/2010. A research facility for wave energy projects has been created off the Islandsberg peninsula in the municipality of Lysekil, off the west coast of Sweden.

The *Atlantic Marine Energy Test Site* (AMETS), located offshore Belmullet, in Ireland, a key part of the Ocean Energy Strategy for Ireland, is in development. Further, a sheltered test site in Galway Bay where 1:4 scale models can be tested without grid-connection has been active.

Outside Europe, a new in-stream tidal energy testing has been set-up in Canada, the *Fundy Ocean Research Centre for Energy* (FORCE), located in the Bay of Fundy, Nova Scotia, with four berths, each with a capacity of 16 MW. A partnership between Oregon State University (OSU) and University of Washington (UW) is developing the *Northwest National Marine Renewable Energy Center* (*NNMREC*) for wave and tidal energy development. Further, *Hawaii's National Marine Renewable Energy Center (HNMREC)*, established in 2008 to accommodate wave and OTEC testing, is planning to provide grid connected berths.

Progress in 2010 – Technologies in the water

At the end of 2010, the installed power is reported with 2 MW for wave energy and 4 MW of tidal stream by the member countries. It has to be remarked that 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. In Korea, the construction of the 254 MW Sihwa tidal barrage power plant, expected to be operational in 2011, will raise the worldwide installed power to ca. 519 MW (France, Canada, Russia, China, Korea, mainly tidal barrages).

Several developers tested the first full-scale devices in open sea, estuarine areas or fast-flowing rivers, during 2010; other technologies are very close to be deployed. The world's first osmotic power prototype in Norway, operating since November 2009, has proven the concept in full scale and during 2010 was used to test improved membranes and water treatment systems.

Progress on **tidal current deployments** was reported in several member countries in 2010. In Canada, the Irish Open Hydro 1-MW turbine was tested in the Bay of Fundy, and was announced as the first commercial-scale turbine deployed in North America. Another technology, the 250 kW TREK turbine, by the Canadian company RSW Inc, was installed in the St. Lawrence River, Quebec (Canada). Verdant Power is working to deploy its horizontal axis turbines also in the St. Lawrence River in the spring of 2011, after the experience acquired during 2006 – 2008 with the RITE project in New York City's East River.

Marine Current Turbines' (MCT) SeaGen (1.2 MW) is installed in Strangford Lough, Northern Ireland, operating since 2008, having produced more than 2.3 GWh. Two further British tidal stream technologies have been deployed in the European Marine Energy Centre (EMEC), the AK1000 (1 MW) turbine from the Atlantis Resources Corporation and the 500 kW demonstrator unit of Rolls Royce/Tidal Generation Ltd. Further, two prototypes have been tested in UK waters, the oscillating hydrofoil Pulse Tidal's 100 kW prototype and the Neptune Proteus NP1000 vertical axis turbine.

The 1.5 MW Morild II floating horizontal-axis prototype from the Norwegian company Hydra Tidal Energy Technology was installed in Lofoten, Northern Norway, in the summer of 2010. The 300 kW Hammerfest Strøm's upgraded tidal prototype was re-installed in the summer of 2009 in Kvalsund, Northern Norway, and the Norwegian company plans to begin the installation of a 1 MW prototype at the European Marine Energy Centre (EMEC).

The Kobold Turbine of Ponte di Archimede International, a floating vertical-axis turbine has been operating in the Strait of Messina, since its installation in 2002. A prototype of 120-150 kW is being built to be placed in the Lomboc Island, Indonesia. Also in Italy, an horizontal axis type floating tidal prototype of 20 kW, developed by Sea Power, has been tested in the Strait of Messina since 2009 and permits for a 500 kW system are expected for the beginning of 2011.

Progress on **wave energy deployments** during 2010 was achieved around the world. In the UK, Aquamarine's device, Oyster 1, installed at EMEC in 2009, undergone sea trials during 2010 and Aquamarine is planning the design of the next-generation Oyster 2. Pelamis Wave Power tested the 750 kW P2 device commissioned by E.ON UK for 4 days and is manufacturing the second 750 kW P2 device for ScottishPower Renewables. The two utilities announced they would join efforts. Wavegen's Limpet oscillating water column (OWC) plant on the Scottish island of Islay has been operating as a demonstration facility for new generation Wells turbines.

Fred Olsen's first full scale prototype "BOLT" has been undertaking sea trials since June 2009 in Norway and plans for deployment of a pre-commercial unit in the UK during 2011 are mentioned. In Ireland, the OE Buoy from Ocean Energy Ltd. is being used as the test platform in Galway Bay and the device with a novel air turbine an electrical control system is expected to be launched very soon. At the full-scale experimental site in Islandsberg, Sweden, several generator units have been tested in the sea by the Swedish company Seabased and Uppsala University. In Denmark, several wave energy developers were active in

2010: a prototype section of the Wave Star device was installed in Hanstholm in September 2009 and its 1:10 scale demonstration version has continued testing in Nissum Bredning. Floating Power plant undertook a second test starting in the spring of 2010 with three wind turbines for testing the combination of wind and wave power. Wave Dragon, after being reinstalled in 2009 in Nissum Bredning, operated until March 2010, being then removed due to problems caused by drifting ice. The Dexa device installed in March 2009 in Nissum Bredning was tested until February 2010. A 1:10 scale model of the Leacon device is under construction and will be installed in the spring of 2011 in Nissum Bredning.

In Spain, PIPO Systems Welcome project was deployed in late 2010 on Canary Islands. The Mutriku OWC breakwater in the Basque Country (Spain), promoted by EVE, with an estimated overall power of about 300 kW, is waiting for the installation of the 16 turbines expected to occur in early 2011. The shoreline 400 kW OWC wave energy pilot plant in the Azores (Portugal), operating since 2005, has multiplied formerly fed-in amounts of electricity into the electrical grid, yielding more than 1200 operational hours in 2010.

Another OWC technology integrated in a breakwater (500 kW) is under construction in South Korea, on Jeju Island, planned to become operational in 2011.

In Australia, Oceanlinx's one-third scale floating OWC device, the MK3PC, was deployed in Port Kembla and operated grid connected from February to May 2010, before being damaged in extreme sea conditions. Carnegie Corporation deployed a single stand-alone CETO unit near Perth in Western Australia. PerpetuWave Power has developed a 1:4 scaled concept prototype, which has been tested in bay type wave conditions in Australia. Wave Rider Energy Pty Ltd is planning to launch its first pilot plant in South Australia in 2011. In New Zealand, WET-NZ's second 2 kW ¼-scale floating device was deployed in April but recovered in May due to failure of a component.

Ocean Power Technologies, Inc. was granted the first license by the Federal Energy Regulatory Commission (FERC) for a 1.5 MW commercial-scale project in the US, and started manufacturing the first 150 kilowatt PB150 PowerBuoy in Oregon.

Key facilitators for ocean energy

INORE, the International Network on Offshore Renewable Energy, emerged from the "PhD pool on Offshore Renewable Energy" founded in Norway, and is now run by and for early stage researchers. Currently, INORE has over 500 individual members, from over 49 countries. 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. This kind of network will bring huge benefits to the offshore energy community. The article "**International Network on Offshore Renewable Energy (INORE): Realising the potential of young researchers and offshore renewable energy**", prepared by the actual Steering Committee, outlines the need for an international network, a brief history of INORE and future plans.

The third International Conference and Exhibition on Ocean Energy (ICOE 2010), organised in October 2010 in Spain by EVE (the Basque Energy Board) and

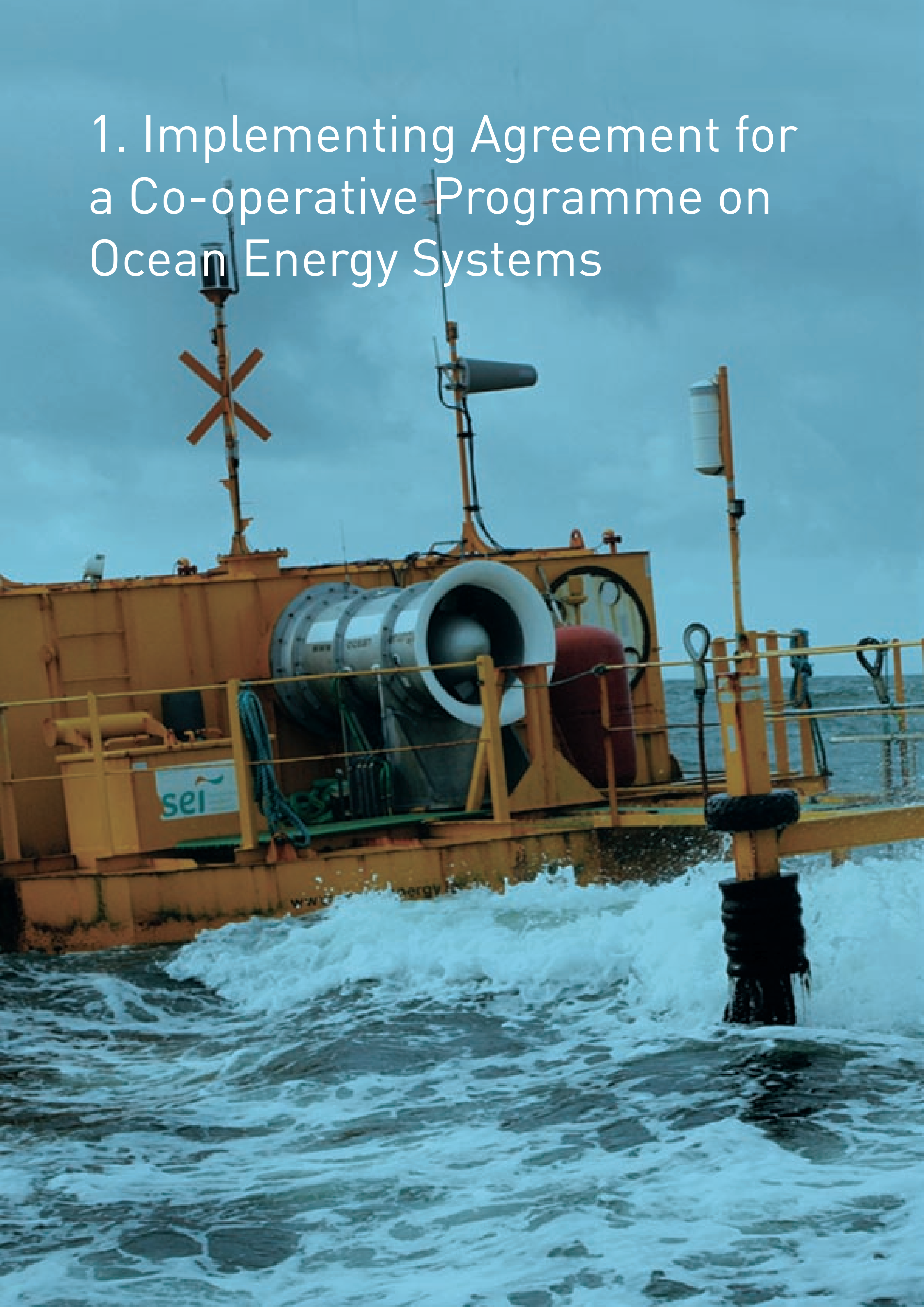
Tecnalia, is seen as a relevant stakeholder meeting. A brief review of the key points emerged in the conference is presented in the joint article "**Moving ocean energy to the industrial scale**" by the session moderators. The key message was the need to progress from the demonstration level to commercial scale initiatives and the importance of a co-ordinated approach to avoid duplication. Several ocean energy facilities in the open sea that have proliferated over the last years, mainly in European countries, are seen as the incubators for the development of prototypes, in which many problems will be faced and overcome (such as permitting, grid access, environmental monitoring, marine operations), thus catalyzing the growing industry of ocean energy. It highlights the consensus in the roundtable discussion among developers that the 2020 aspirations of 2-4 GW installed capacity are seen as realistic if the appropriate mechanisms are implemented, thus following a similar trend as the wind energy sector has experienced.

The article **"Why wave energy – market driver analysis for investors and policy makers"** brings attention to the key factors that need to be gathered and considered when making full analysis and decision regarding the reasons for investing both funds and time in the wave energy sector. Cost considerations are the most pressing concern for wave energy, requiring effective policies, legislation and implementation strategies. The author concludes that the majority of market drivers and indicators are positive toward wave energy at the present time, when macro-economic and socio-economic factors are considered.

Dr. Ana Brito e Melo
Secretary to the Executive Committee
Wave Energy Centre, Portugal

PHOTO BY JOHNTEX, 2006

1. Implementing Agreement for a Co-operative Programme on Ocean Energy Systems



1.1 What is an IEA Implementing Agreement?

Implementing Agreements are multilateral technology initiatives that enable experts from governments and industry to work together to carry out programmes and projects on energy technology research, development and deployment.

There are currently 42 Implementing Agreements (IAs), within the International Energy Agency, working in the areas of:

- cross-cutting issues (information exchange, modelling, technology transfer)
- efficient end-use technologies (buildings, electricity, industry, transport)
- fossil fuels (greenhouse gas mitigation, supply, transformation)
- fusion power (international experiments)
- renewable energies and hydrogen (technologies and deployment)

Any public or private organisation within OECD member or non-member countries, international organisations, or non-governmental organisations may participate. Each IA signatory designates a representative to the board of directors (Executive Committee) that manages the work programme of the Agreement.

The scope and strategy of each IA is in keeping with the IEA shared goals: energy security, environmental protection, economic growth and engagement worldwide. Typically, the work includes: basic and applied research, technology development and pilot plant technology assessment, feasibility studies, environmental impact studies, market analysis, policy implications, information exchange of research results, and scientist exchange programmes.

The IEA Framework for International Technology Cooperation specifies the minimum legal and management requirements for IAs, including the mandate, the nature of agreements, participation and withdrawal, and length of term.

The work conducted by the IAs is supervised by the IEA Committee on Energy Research and Technology (CERT) which promotes the development, demonstration and deployment of technologies to meet challenges in the energy sector.

1.2 The Implementing Agreement on Ocean Energy Systems

The Implementing Agreement on Ocean Energy Systems (OES-IA) was initiated by three countries in 2001. Since then, further fifteen countries have signed the OES-IA. The participants come from governments, R&D institutions, National laboratories, agencies and industry in the following countries: 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 and South Africa, ordered by sequence of joining the Agreement.

The first term of the OES-IA originally ran from 2001 until 2006 and was then extended. The second term runs from October 2006 until 18 October 2011. Each new term is requested for a maximum of five years. During 2010, the CERT agreed on a new schedule for implementation of the review process of IAs and request for extension. Therefore all IAs were asked to standardise the end-of-term dates. **The end-of-term date for the OES-IA was set for 28 February 2012, thus prolonging the current term by four months. A request for a new 5-year term shall be submitted to the CERT during 2011.**

The "request-for-extension" process is an opportunity for the Executive Committee to discuss its accomplishments over the past term and to make specific plans for the next term. This discussion was initiated in the October 2010 ExCo meeting with the preparation of the "End-of-Term Report" and a new "Strategic Plan" for a new five-year term.

The OES-IA brings together countries to advance research, development and demonstration of conversion technologies to harness energy from all forms of ocean renewable resources, such as tides, waves, currents, temperature gradient (ocean thermal energy conversion and submarine geothermal energy) and salinity gradient for electricity generation, as well as for other uses, such as desalination, through international cooperation and information exchange.

The OES-IA covers all forms of energy generation, in which sea water forms the motive power, through its physical and chemical properties (Figure 1). It does not presently cover offshore wind generation, since sea water is not the motive power (offshore wind is covered by the Wind Energy Implementing Agreement).

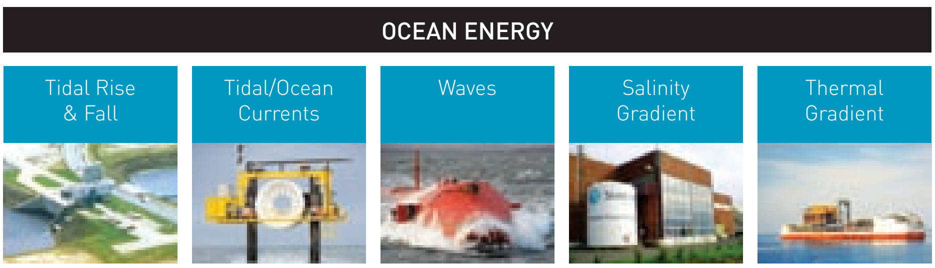


Fig. 1. Principal Forms of Ocean Energy

According to the “Strategic Plan 2007-2011” the OES-IA has the following vision, mission and objectives, as presented in table 1.

“STRATEGIC PLAN 2007-2011”
Vision
To realise, by 2020, the use of cost-competitive, environmentally sound ocean energy on a sustainable basis to provide a significant contribution to meeting future energy demands.
Mission
To facilitate and co-ordinate ocean energy research, development and demonstration through international co-operation and information exchange, leading to the deployment and commercialisation of sustainable, efficient, reliable, cost-competitive and environmentally sound ocean energy technologies.
Strategic Objectives:
1. To actively encourage and support the development of networks of participants involved in research, development and demonstration, prototype testing and deployment, policy development and deployment, and to facilitate networking opportunities.
2. To become a trusted source of objective information and be effective in disseminating such information to ocean energy stakeholders, policymakers and the public.
3. To promote and facilitate collaborative research, d evelopment and demonstration to identify and address barriers to, and opportunities for, the development and deployment of ocean energy technologies.
4. To promote policies and procedures consistent with sustainable development.
5. To promote the harmonisation of standards, methodologies, terminologies and procedures where such harmonisation will facilitate the development of ocean energy.

Table 1. Vision, Mission and Objectives according to the “OES-IA Strategic Plan 2007-2011”

1.3 Membership

Membership of the OES-IA is by invitation of the Executive Committee to country governments. The ExCo has an active interest in securing new members and the OES-IA has continued to show steady growth during its ten years of operation and this trend seems set to continue (Figure 2).

The Republic of Korea and **South Africa** became the newest members of the OES-IA in early 2010, bringing the number of members to eighteen. During the year, the OES-IA Executive Committee officially renewed its invitations to **France, the Netherlands, India and Chile** and invited Indonesia to join for the first time.

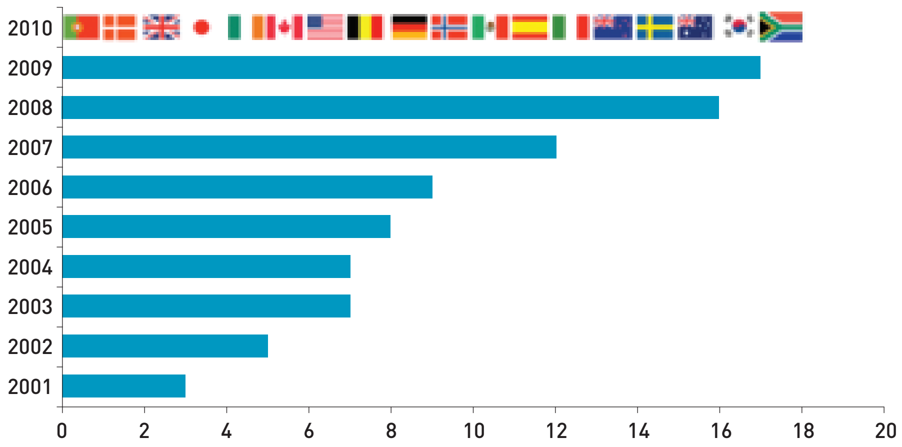


Fig. 2. OES-IA Membership Growth

When country governments accept the invitation to join the OES-IA, they may nominate Contracting Parties from within their own agencies or appoint other parties to represent them (Table 2). 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.

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	Oceanlinx
2010	Korea	Government of the Republic of Korea
	South Africa	South African National Energy Institute (SANERI)

Table 2. Contracting Parties to the OES-IA (status: Dec. 2010)

In 2010 there were personnel changes among the Contracting Party representatives and alternates (See 2010 Executive Committee for Delegates, Alternate Members, and Operating Agent representatives who served in 2010).

1.4 Executive Committee Meetings

The Executive Committee is the decision-making body of the IA and meets twice a year to discuss the work programme and share information among members. In 2010, ExCo meetings were held in Wellington, New Zealand (22-23 April 2010) and in Dublin, Ireland (30 September – 1 October 2010).

In 2010, Dr. John Huckerby was re-elected as chairman for 2011-2012 and Mr. Eoin Sweeney (Irish delegate) and Mr. José Villate (Spanish alternate) appointed as vice-chairs for the same period.

18th ExCo meeting
22-23 April 2010, Wellington, New Zealand

This meeting was hosted by AWATEA, the New Zealand contracting party to the OES-IA, in Wellington, with 16 participants. China and India attended the meeting as observers. The New Zealand delegate John Huckerby (OES-IA chairman) was the local organiser of the meeting.

19th ExCo meeting
30 September – 1 October 2010, Dublin, Ireland

The 19th ExCo meeting was held in Dublin, Ireland, with 22 participants. This meeting was hosted by the Sustainable Energy Authority of Ireland. Indonesia attended the meeting as observer. The delegate member from Ireland, Mr. Eoin Sweeney, was the local organiser of the meeting. The chairman of the Committee on Energy Research and Technology (CERT), Mr. Peter Cunz, attended the meeting.

Fig. 3. 19th OES-IA ExCo meeting group in Dublin, Ireland

1.5 Collaborative Research

Within the IA's work programme there are collaborative activities in which participants may choose to take part (except for the mandatory Task 1). At the end of 2010, the work programme of the OES-IA comprised three collaborative activities (Table 3). The management of these Tasks is under the responsibility of the Operating Agents (OA).

Task 1	**Review, Exchange and Dissemination of Information on Ocean Energy Systems**	ACTIVE
OA:	Originally INETI/LNEG – PORTUGAL; Wave Energy Centre, since October 2010	
Duration:	From 2001 (indefinitely)	
Task 2	**Development of Recommended Practices for Testing and Evaluating Ocean Energy Systems**	CONCLUDED
OA:	Ramboll – DENMARK	
Duration:	2002-2003; 1st Ext 2004-2006; 2nd Ext 2007-2009	
Task 3	**Integration of Ocean Energy Plants into Distribution and Transmission Electrical Grids**	ACTIVE
OA:	Powertech Labs – CANADA	
Duration:	2007 – 2009; 1st Ext 2009 – 2010	
Task 4	**Assessment of Environmental Effects and Monitoring Efforts for Ocean Wave, Tidal and Current Energy Systems**	ACTIVE
OA:	Department of Energy – USA	
Duration:	2009 – 2011	

Table 3. OES-IA Research Projects (status: Dec. 2010)

Country	**Task 1** *Exchange of Information*	**Task 3** *Electrical Grids*	**Task 4** *Environmental Effects*
Portugal	X		
Denmark	X		
United Kingdom	X	X	X
Japan	X		
Ireland	X	X	X
Canada	X	X	X
United States	X		X
Belgium	X		
Germany	X		
Norway	X		X
Mexico	X		
Spain	X	X	X
Italy	X		
New Zealand	X	X	X
Sweden	X		X
Australia	X		
Korea	X		X
South Africa	X		

Table 4. Participants in each Task of the OES-IA work programme (status: Dec. 2010)

1.6 Collaborative Activities with the IEA

In addition to its own collaborative activities, the OES-IA Executive Committee aims to collaborate with other Implementing Agreements and give input to several other IEA initiatives. During 2010, these included:

ECES WORKSHOP "Energy Storage: Matching Supply and Demand in the Future"

14-16 July 2010, Bad Tölz, Germany

The IEA *Implementing Agreement on Energy Conservation through Energy Storage* (ECES) held a second workshop on the future role of energy storage and invited all Implementing Agreements to participate.

The leading question at the workshop was "Do you need energy storage?". Presentations given by the Implementing Agreements highlighted individual energy storage needs. The discussion made clear that it would be very valuable to have a characterisation of the different storage demands, in order to identify suitable storage technologies.

Presentations are available at: http://iea-eces.org/energy-storage/news/workshop-2010.html

Electricity Coordination Group (ECG) meeting "Electricity Grids – a key enabler in the delivery of a sustainable energy policy"

27 April 2010, IEA Headquarters, Paris

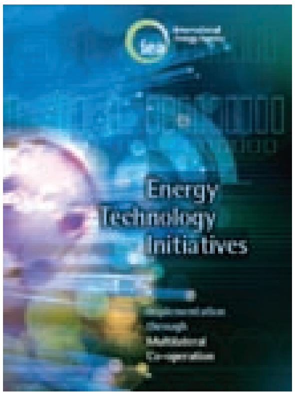
The crucial role of the electricity transmission and distribution networks in the delivery of energy policy objectives was recognised via the establishment of the *IEA Implementing Agreement on Electricity Network Analysis, Research & Development* (ENARD), in July 2006. At an internal level, the IEA Electricity Coordination Group (ECG) was established.

The objective of the topical workshop, organised in conjunction with the ECG and the IEA Secretariat, was to provide a series of high level regional perspectives on the crucial importance of electricity networks and present a series of emerging policy messages and highlights from ENARD's first 4 years of operation. The conclusions and recommendations from the workshop were intended to form a key input in relation to future international collaborative activities in this area and beyond, under the auspices of the IEA.

Energy Technology Systems Analysis Programme (ETSAP)

The IEA *Implementing Agreement on Energy Technology Systems Analysis Programme* (ETSAP) has initiated the development of the energy technology data source (E-Tech-DS), including a series of four-page technology briefs, consisting of basic information on energy sources and technology to be used by technical-economic models, energy experts, policymakers, private investors and media. The OES-IA is reviewing the Marine Energy Technology Brief.

More information: http://www.etsap.org/E-techDS



Technology Initiatives Implementation

The OES-IA has given inputs to the publication of the *"Energy Technology Initiatives: Implementation through Multilateral Co-operation"*, on 30 July 2010, which highlights the significant accomplishments of the IEA Implementing Agreements.

1.7 Links with Other Projects and Initiatives

The OES-IA has links with several international organisations and networks.

International Electrotechnical Commission's Technical Committee 114

The OES-IA is collaborating with the Technical Committee (TC) 114, Marine Energy – Wave and Tidal Energy Converters, to develop international standards for wave and tidal energy technologies. TC114 has 13 participating member countries and 7 observer members. Thirteen of these 20 members are also members of OES-IA, and further the Canadian delegate of the OES-IA is the chairman of the TC114. The similarity of memberships ensures that there is close communication between the two organisations.

EquiMar

EquiMar – Equitable Testing and Evaluation of Marine Energy Extraction Devices in terms of Performance, Cost and Environmental Impact is a collaborative research and development project involving a consortium of 23 European partners. The aim of EquiMar is to deliver a suite of protocols for the equitable evaluation of marine energy converters (based on either tidal or wave energy) to harmonise testing and evaluation procedures. This project has received funding from the European Community's Seventh Framework Programme FP7/2007-2013. Since May 2009, the chairman serves the EquiMar Project Steering Committee on behalf of the OES-IA. A number of OES-IA ExCo representatives are directly involved in the EquiMar project work.

Intergovernmental Panel on Climate Change Special Report on Renewable Energy Resources and Climate Change Mitigation

Five members of the Executive Committee have been nominated by their governments and accepted by the Intergovernmental Panel on Climate Change (IPCC) to participate in the draft of a Special Report on Renewable Energy Resources and Climate Change Mitigation. Four of the ExCo members are collaborating on the Ocean Energy chapter and one on the Geothermal Energy chapter. The final version of the report is planned to be completed by mid-2011.

International Network on Offshore Renewable Energy (INORE)

INORE is a network for researchers working with issues related to offshore renewable energy: wave, tidal, or offshore wind energy. INORE brings together researchers from around the world to meet, collaborate, and share knowledge. The OES-IA plans to encourage this network and during 2010 the OES-IA supported INORE financially for the development of its new website.

European funded projects

Most of the European representatives of the OES-IA are involved in several European research consortiums funded by the European Commission. These projects deal with a great variety of topics and information is shared among members.

European funded projects on Ocean Energy

Waveplam	**WAVEPLAM – WAVe energy PLAnning and Marketing** (2007-2010) www.waveplam.eu Coordinator: Ente Vasco de la Energia (EVE), Spain
CORES	**CORES – Components for Renewable Ocean Energy Systems** (2008-2011) http://hmrc.ucc.ie/cores Coordinator: UCC Hydraulic and Marine Research Centre (HMRC), Ireland
EquiMar	**EQUIMAR – Equitable testing and evaluation of marine energy extraction devices in terms of Performance, Cost and Environmental Impact** (2008-2011) www.equimar.org Coordinator: Edinburgh University, United Kingdom
wavetrain2	**WAVETRAIN2 – multinational Initial Training Network (ITN) on wave energy** (2008-2012) www.wavetrain2.eu Coordinator: Wave Energy Centre, Portugal
ORECCA	**ORECCA – Off-shore Renewable Energy Conversion platforms** (2010-2011) www.orecca.eu Coordinator: Institute Fraunhofer Gesellschaft, Germany
MARINA PLATFORM	**MARINA PLATFORM – Marine Renewable Integrated Application Platform** (2010-2014) www.marina-platform.info Coordinator: Acciona Energia, Spain
sowfia Streamlining of Ocean Wave Farm Impact Assessment	**SOWFIA – Streamlining of Ocean Wave Farm Impacts Assessment** (2010-2011) Coordinator: University of Plymouth, United Kingdom

Table 5. European funded projects related to ocean energy in which European representatives of the OES-IA are involved

2. Task status reports

Task 1 – Review, Exchange and Dissemination of Information on Ocean Energy Systems

Operating Agent: Ana Brito e Melo, Wave Energy Centre, Portugal

Task 1 is a mandatory Annex of the OES-IA work programme which has been running since the formation of the OES-IA. The objective of this Task is to collate, review and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of ocean energy systems. Access to this information should facilitate further development and adoption of cost-effective ocean energy systems. In addition, the results of this Task aim to facilitate identification of further annexes, as well as continuing to promote information exchange.

In 2010 the Executive Committee discussed that a new visual identity for the OES-IA was essential to make all its disseminated documents easily recognizable and identifiable. Further, the need to re-design the OES-IA website aims to appeal to a wide range of audiences, both technical and non-technical. Therefore, the ExCo approved the development of a Communication Plan for the OES-IA, which was initiated in late 2010 and should lead to a new set of activities in 2011, in order to renew the image of the OES-IA.

The lead of Task 1 has been under the responsibility of the Portuguese Contracting Party LNEG (former INETI). Due to the resignation of the Portuguese delegate as representative from Portugal, as well as Operating Agent of Task 1, the Wave Energy Centre took temporarily the role of Operating Agent, in September 2010, until the restructuring of this Task is finalized.

The OES-IA Bulletin

In October 2010, the first 6-page Bulletin was published. This highlights the 2010 achievements on ocean energy presented in the 19th ExCo meeting by the delegates. It is available online and was distributed to a wide range of audience in all member countries.

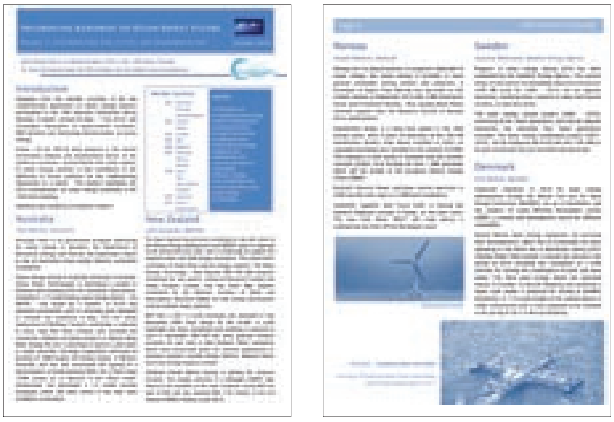


Fig. 4. Screenshot of the OES-IA Bulletin October 2010 (page 1 and page 4)

PARTICIPATION IN INTERNATIONAL CONFERENCES

Dissemination of OES-IA activities has been an ongoing process, through the presence of OES-IA representatives in well-known conferences related to ocean energy. Such events are the best way to spread awareness about the OES-IA role and activities. The table below presents the different events in 2010 where OES-IA was represented.

International Events
3rd Annual Global Marine Renewable Energy Conference 14-15 April 2010, Seattle, USA
4th Annual Aotearoa Wave and Tidal Energy Association Conference 19-20 April 2010, New Zealand, Wellington
Ocean Energy 2010 – Annual Conference of the European Ocean Energy Association 5-7 May 2010, Brussels, Belgium
Workshop "Oceans – A Source of Energy" 17-18 May 2010, Lisbon, Portugal
Sustainable Ocean Summit organized by the World Ocean Council 15-16 June 2010, Belfast, UK
3rd International Conference on Ocean Energy (ICOE2010) 3-8 October 2010, Bilbao, Spain

PAPERS PUBLISHED IN 2010

- Brito-Melo and J. Huckerby, "*The International Energy Agency's Ocean Energy Systems Implementing Agreement: Achievements to Date*", Proc. of the Workshop on "Oceans as a Source of Energy", Lisbon, 17–18 May 2010.
- J. Huckerby, J. Bard, J. Villate and A. Brito-Melo, "*Ocean Energy Systems Implementing Agreement: An International Vision for Ocean Energy and a Review of 2009-2010 Achievements*", Proc. of the 3rd International Conference on Ocean Energy, Bilbao, Spain, 3-8 October 2010.

ORGANISATION OF WORKSHOPS AND TECHNICAL VISITS FOR THE OES-IA TEAM

During 2010, two internal workshops were organized for the OES-IA group on the occasion of the 18th ExCo meeting in Wellington:

1. Strategic Planning (22 April 2010)
2. Marketing & Publishing (23 April 2010)

These workshops, organized by the New Zealand delegate and moderated by external consultants, were useful to initiate the discussion for future activities under the OES-IA: the need to define a strategic plan for the next 5-year term and the requirement to develop a Communication Plan for the OES-IA.

A workshop on the "Commercial Deployment of Marine Energy Projects" was organized in Dublin, Ireland, for occasion of the 19th ExCo meeting (see Fig. 5). The aim of this workshop was to position industry for the challenges and opportunities associated with large-scale utilization of ocean energy. This event was organised by the Sustainable Energy Authority of Ireland with the support of Innovation Norway and Bord Gáis Éireann (the Irish gas utility). The workshop focused on the challenges of building and operating large marine energy projects (+250MW) and addressed all aspects of construction, logistics and operations and maintenance, drawing on the experience of the offshore wind and oil and gas industries. Attendees were drawn from the engineering, contracting and marine operations sectors.

The presentations are available at: http://www.seai.ie/Renewables/Ocean_Energy/OE_O_and_M_Workshop

PROGRAMME

Commercial Deployment of Marine Energy Projects

29th September 2010, Dublin, Ireland

Welcome and Introduction
Prof. J. Owen Lewis, CEO, SEAI

The IEA Vision for Ocean Energy
John Huckerby, Chairman, OES-IA

Ireland's Marine Renewables Strategy in Perspective
Eoin Sweeney, Head, Ocean Energy Development, SEAI

Industrial Implications of realising the EO-EA Roadmap
Karl Christian Stromsem, Offtek, Norway, representing the EU-OEA

A Utility Perspective on the Utilisation of Marine Renewable Energy
Ulf Tisell, Vattenfall

An OE Developer's Experience of Deployment Issues
Open Hydro, Ireland

The Norwegian Experience in the Oil and Gas Sector – Lessons for the Renewables Sector
Leif Røv, AAK, Norway

Experience in the Deployment of Offshore Wind Projects
Jochen Bard, Fraunhofer Institute for Wind Energy and Energy Systems Technology IWES

Design Challenges for Wave Energy Projects
Noel Halloran, Technology from Ideas

Design for Installation Subsea maintenance, and Recovery of a Tidal Turbine
Hender Blewett, IHC Engineering Business

US Perspectives on the Deployment of Marine Energy Projects
Greg McMurray, Pacific Energy Ventures, US

Two technical visits were organized by the Irish delegate on the occasion of the 19th ExCo in Dublin, Ireland:

1. Technical visit to the Marine Current Turbine prototype in Strangford Narrows, Northern Ireland, known as "SeaGen", operational since 2008 (see Fig. 5). It uses twin 16 m diameter rotors, with an installed power of 1.2 MW at a current velocity of 2.4 m/s.

2. Technical visit to the OpenHydro Greenore Technical Centre (see Fig. 6) where the turbine installed in EMEC in 2008 and the pre-commercial unit for Nova Scotia Power (Bay of Fundy, Canada) were fabricated.

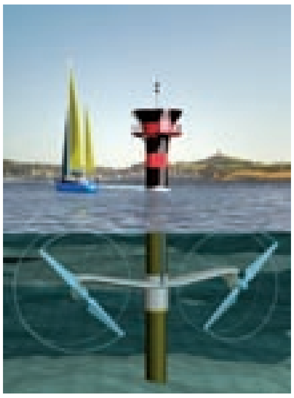



Fig. 5. Marine Current Turbines prototype artistic impression (left) and in Strangford Narrows (right)

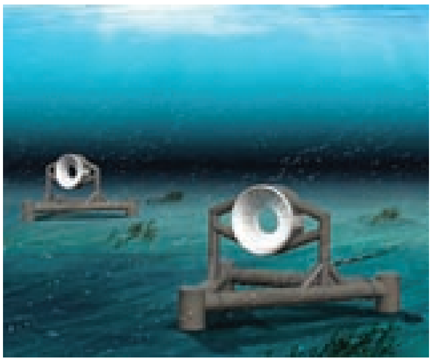



Fig. 6. Open-Centre Turbine artistic impression (left) and at OpenHydro Greenore Technical Centre (right)

Task 2 – Development of Recommended Practices for Testing and Evaluating Ocean Energy Systems

Operating Agent: Kim Nielsen, Ramboll, Denmark

Overall objective

The objective of this Task was to develop recommended practices for testing and evaluating ocean energy systems. Ocean energy systems are at the research and development and pre-commercial demonstration stage of technology development. A major challenge to developers and those supporting development in this area is that there are a number of different resource types within ocean energy systems (including waves, tides, tidal currents, salinity and thermal differentials) and several different approaches to extracting energy from each resource type. This lack of convergence creates difficulty in comparing systems as the underlying assumptions with respect to power production, generator capacity and cost statements are very different. Task 2 attempts to address this issue by providing guidelines, with the intent to lay the groundwork for the future establishment of standards, for theoretical, model and prototype testing, preliminary cost assessments and the presentation of results.

In 2006, the Executive Committee of the OES-IA agreed to extend the Annex to address prototypes and the overall objective of the extended work programme is to provide the necessary basis in order to present the performance of different ocean energy systems in a comparable format.

Work Programme

In the first period, the work programme included collecting and analysing information on testing facilities and testing procedures to develop standards for presentation of technical design and data, and for assessment of system performance. The 2003 report, *"Development of Recommended Practices for Testing and Evaluating Ocean Energy Systems"*, was the first output from this task, providing an overview of testing facilities in the OES-IA member countries and guidelines for standards for testing, preliminary cost assessment and presentation of results.

In the second period, the work programme was structured to cover sea testing, with the following three work packages (WP):

	2007 – 2009 Work Programme
WP 1:	**Generic and site related Wave & Tidal Data** Four generic scatter diagrams that reflect typical wave conditions and typical tidal flow conditions at different member states' coastlines will be compiled. The goal is to enable comparison between the performance of different wave energy systems and of different tidal energy systems. • Task 1.1 Generic and site related Wave Data • Task 1.2 Generic and site related Marine Current Data
WP 2:	**Development and Evaluation Protocol for Ocean Energy Systems** The Protocol provides a document that, in simple terms, explains necessary steps in the development of ocean energy systems. The protocol aims at explaining in a common language the objective and expected outcome of each step for developers and supporting bodies. Criteria for moving from one step to the next will be explained and discussed. • Task 2.1 Development Protocol Wave • Task 2.2 Development Protocol Tidal
WP 3:	**Guidelines For Open Sea Testing And Evaluation of Ocean Energy Systems** Guidelines for different types of ocean energy systems based on best practice and experience from the ocean energy community. Task 3.1 Monitoring and data acquisition Wave & Tidal Task 3.2 Data preparation and presentation of results Wave & Tidal Task 3.3 Guidelines on design, safety and installation procedures Wave & Tidal

Key deliverables

All reports produced under Task 2 are available for download at the OES-IA website: www.iea-oceans.org

Task 2 Reports

• ***Report T02-0.0 Development of Recommended Practices for Testing and Evaluating Ocean Energy Systems, OES-IA Annex II Summary Report***
K. Nielsen, Ramboll (2010)

• ***Report T02-1.1 Generic and Site-Specific Wave Data***
K. Nielsen, Ramboll and T Pontes, INETI (2010)

• ***Report T02-1.2 Guidance for Assessing Tidal Current Energy Resources***
A. Cornett, NRC-CHC (2008)

• ***Report T02-2.1 Guidelines for the Development & Testing of Wave Energy Systems***
B. Holmes, HMRC, UCC Ireland (2010)

• ***Report T02-2.2 Tidal Energy Development Protocol***
S. Bahaj, L. Blunden and A. A. Anwar, University of Southampton (2008)

• ***Report T02-3.1 Preliminary Wave Energy Device Performance Protocol***
G. Smith, Heriot-Watt University and J. Taylor, Edinburgh University (2007)

• ***Report T02-3.2 Preliminary Tidal-current Energy Device Performance Protocol***
S. J. Couch and H. Jeffrey, Edinburgh University (2007)

• ***Report T02-3.3 Guidelines for the design Basis of Marine Energy Converters***
P. Davies, Lloyd's Register EMEA, (2009)

Task 3 – Integration of Ocean Energy Plants into Distribution and Transmission Electrical Grids

Operating Agent: Gouri S. Bhuyan, Powertech Labs Inc, Canada

Background & Scope

The overall aim of this Annex is to provide a forum for enabling co-operative task-shared and cost-shared research activities related to integration of wave and tidal current power plants into electrical grids. The work programme of the Annex, consisting of the three following work packages (WP), was approved by the OES-IA Executive Committee in March 2007.

- WP 1 (Subtask 3.1) – Identify potential differences and opportunities associated with the longer-term large scale integration of wave and tidal current energy plants, in comparison with wind energy, and identify improvements to the existing interconnection guidelines to facilitate early stage pilot wave and tidal projects.
- WP 2 (Subtask 3.2) – Review best practices for characterizing different generation technologies and develop relevant specifications for wave and tidal current conversion processes.
- WP 3 (Subtask 3.3) – The revised scope of this work package involves producing a report that will present some key findings/information generated through the completed WP 1 & 2, as well as include case studies demonstrating modelling of integration of wave and tidal current plants to distribution and transmission networks.

The work programme also included "Coordination" activities with other relevant IEA initiatives.

Participating Countries and Organizations

The ExCo member countries that are participating in the work programme of the Annex are Canada, Ireland, United Kingdom, Spain and New Zealand. Funding for the overall management of the Annex activities has been provided by Powertech Labs, the UK Department of Energy and Climate Change (DECC), Tecnalia of Spain and AWATEA of New Zealand.

The participating organizations and the corresponding enabling funding contributors for this Annex are as follows:

- Powertech Labs with direct & indirect financial contribution from BC Hydro & Powertech Labs, Canada, Bonneville Power Administration, US, Oregon Wave Energy Trust (OWET), US, and Asia Pacific Partnership (APP) Programme of Environment ,Canada
- Hydraulic Maritime Research Centre (HMRC), with financial contribution from the Sustainable Energy Ireland (SEI), and Science Foundation of Ireland
- Tecnalia, Spain
- Aotearoa Wave and Tidal Energy Association (AWATEA), New Zealand
- AEA Technology, UK, through the Department of Energy & Climate Change (DECC), UK

Achievements and Progress in 2010

In 2010, Work Package 2, led by HMRC, was completed and the following report was published:

- IEA-OES Doc. T0321 on *"Dynamic characteristics of wave and tidal energy converters & a recommended structure for development of a generic model for grid connection"*. A common or generic power conversion chain representing the majority of ocean wave and tidal energy devices is identified in this report, based on the feedback received from a questionnaire submitted to a range of ocean energy device developers.

Work Package 3, co-led by Tecnalia and Powertech Labs, was initiated in January 2010. The activities of this WP progressed well during the year. A final face-to-face meeting of the Annex participants was held in Bilbao, Spain, on 5 October 2010 to discuss WP3 activities. A draft WP3 report "Integrating wave and tidal current power: case studies through modelling and simulations" consisting of the following sections has been prepared:

- Section 1: This is an introductory section discussing variability of wave and tidal current resources as well as generation characteristics of some wave and tidal current conversion processes. The section also briefly discusses different grid codes.
- Section 2: This section presents how potential grid integration issues can be managed considering various factors, including factors like site, characteristic of conversion systems, layout of devices, and system control.
- Section 3a: This sub-section presents case studies illustrating integration of wave energy plants to distribution grid.
- Section 3b: This sub-section presents case studies illustrating integration of aggregate tidal current & wave energy plants to a larger power system at transmission levels considering various long-term system scenarios.

This WP draft report was sent to several external experts in December 2010 for a technical review prior to finalization and submission to the Executive Committee of the OES-IA. It is expected that the final WP3 report will be sent for approval by the OES-IA Executive Committee in early 2011 and after that the report will be published.

Task 4 – Assessment of Environmental Effects and Monitoring Efforts for Ocean Wave, Tidal and Current Energy Systems

Operating Agent: Alejandro Moreno (USA Delegate), United States Department of Energy (DOE), USA

Objectives

There is currently a wide range of different ocean energy technologies and devices in development around the world. However, data on the possible environmental effects of these technologies is equally dispersed amongst different countries and developers. The objectives of Annex IV are: 1) to expand baseline knowledge of environmental effects and, particularly, environmental monitoring methods, 2) to ensure that this information is widely accessible, 3) to make available any proven mitigation strategies, and 4) to foster efficient and timely government oversight and public acceptance. To accomplish these objectives, Annex IV member countries will collaborate to create a keyword-searchable, publically available database of previously compiled monitoring information to evaluate environmental effects. The database will include existing syntheses, case study reports compiled as part of this effort and selected relevant analogues. Annex IV will address ocean wave, tidal and ocean current energy development, but not ocean thermal energy conversion (OTEC) or salinity gradients. The construction of the database will be followed by a comprehensive report with a worldwide focus on monitoring and mitigation methods and best practices, including findings from the database, the results of an experts' workshop and lessons learned from the project.

Achievements and Progress in 2010

In early 2010, the U.S. tasked one of their national laboratories, Pacific Northwest National Laboratory (PNNL), to lead the process of database development, data gathering and analysis to support the objectives of Annex IV. PNNL began development of the international Annex IV database (Knowledge Management System – KMS), in conjunction with ongoing US – focused database efforts to support DOE-sponsored ocean energy studies of environmental effects. PNNL also hired the Irish Marine Institute to organize and host an experts' workshop on environmental effects of ocean energy development, held in Dublin during September 2010. Fifty-eight experts from eight countries participated in the workshop; a workshop report was finalized in December 2010. The most important outcomes of the workshop were: 1) a re-alignment of the data gathering objectives to gather data concerning environmental effects of ocean energy projects, with the intent of targeting specific datasets as they are needed for analysis; and 2) the introduction of a cadre of scientists from eight nations interested in contributing to the Annex IV work, as well as acting as ambassadors among their colleagues in support of the Annex. DOE and PNNL staff also attended the UK National Environmental Research Council (NERC) workshop on environmental effects of ocean energy to promote collaboration between NERC and Annex IV activities.

Through a competitive solicitation, PNNL hired a consortium of the Wave Energy Centre (Portugal) and the University of Plymouth (UK) to assist with the collection and analysis of Annex IV environmental effects data. Representatives of the consortium attended the experts' workshop and, in collaboration with PNNL, developed a data input form for metadata on ocean energy environmental effects, based on advice from the experts at the workshop.

OES-IA workshop on environmental effects of ocean energy development, Dublin, September 2010

Activities Planned for 2011

During 2011, the Wave Energy Centre and the University of Plymouth will contact ocean energy technology and project developers, utilities, universities and researchers to gather data on environmental effects. PNNL will finish development of the database for Annex IV and begin to link data and datasets into it. The Wave Energy Centre and the University of Plymouth will also begin preliminary analyses of the data, in collaboration with PNNL.

3. International situation on ocean energy in participating countries

*Member countries – ordered by sequence of joining

Portugal

Paulo Justino, Laboratório Nacional de Energia e Geologia (LNEG)

In 2010, plans were announced to deploy and test off Portugal mainland several wave energy converters, namely the point absorber, Wavebob (Irish technology), WaveRoller (nearshore bottom-mounted surge device) in Peniche (80 km north of Lisbon), as well as Oceanlinx oscillating water column (a multi-OWC platform). The creation of an Offshore Energy Institute was proposed. Research and development continued to be focused on oscillating water columns, with efficiency improvement at the Pico plant and several other actions concerning floating oscillating water column plants.

OCEAN ENERGY POLICY

During 2008, the government appointed REN – Redes Energéticas Nacionais (National Energy Networks) S.G.P.S., S.A. to create a company to manage the Wave Energy Pilot Zone. In 2010, the government approved the minutes for the contract with REN – Resolution from the Council of Ministers nº49/2010 (1 July 2010) which led to its signature. A company named ENONDAS was created to manage the Pilot Zone.

RESEARCH & DEVELOPMENT

Instituto Superior Técnico (IST) and **Laboratório Nacional de Energia e Geologia, IP (LNEG)** have been actively co-operating in research and development. Special attention has been devoted to the numerical simulation of Wave Energy Converters (WECs), overall performance, optimization and control, as well as to tank testing. IST and LNEG have improved their capability to suitably model the energy conversion chain (from waves to electrical energy) and mooring system and the optimal design/specification of their structural and mechanical components. Special care has been assigned to floating oscillating water columns. Model testing of a point absorber has been carried out at a 28 m by 12 m irregular wave tank at Faculdade de Engenharia da Universidade do Porto (FEUP). The design of mooring systems of floating nearshore WECs and the approach to the mooring problem for arrays of WECs have been tackled by the IST team. The study of self-rectifying air turbines to be used in oscillating water columns was a permanent research subject during 2010. As a partner of ORECCA project, LNEG has carried out the assessment of wind and wave resources for the offshore European Atlantic area. The improvement of a Geographical Information System (GIS) database developed at LNEG for site selection of wave energy farms continued to provide guidance for installation of wave energy devices in the country.

Wave Energy Centre (WavEC) is a private non-profit association created is 2003. WavEC's objective is to promote and support cooperation between companies, research and financing institutions and other entities, aiming at the development, promotion, support for commercialization and transfer to the industry of wave energy technologies. Main research activities by WavEC in 2010 were conducted within publicly funded competitive projects. Activities in the following projects have started in the current year:

- SURGE – Simple Underwater Renewable Generation of Electricity (EC funding, € 3 million, 3 years) – The objective of this project is to build, install and test a prototype of the WaveRoller technology in the Atlantic Ocean, nearshore Peniche, Portugal.
- Road-Map – Methodologies for Design, Monitor and Update Strategic Roadmaps: Application to Marine Energies Development in Portugal (national funding; € 200 thousand, 3 years) – The objective of this project is to bring an engineering systems approach to the development of a novel design methodology of roadmaps for renewable and clean energy systems deployment and its application to the design of the Portuguese roadmap for marine energies.
- Structural Design of Wave Energy Devices, funded by the Danish Council for Strategic Research (€ 2.6 million, 5 years, Coordinator: Aalborg University).
- FAME – The Future of the Atlantic Marine Environment (national funding, € 3.5 million, 3 years) – This project will be carried out by partners from 5 countries that have interest, knowledge and expertise in the marine environment, ranging from seabird tracking & monitoring to mapping, data analysis and engagement with the offshore renewable energy and fisheries sectors.

Kymaner is a small-medium enterprise (SME) focused on the demonstration of the validity of the oscillating water column (OWC) approach for the exploitation of wave energy. During 2010 and going into 2011 the company has been concentrated on:

- Preventive maintenance of the Pico plant, now fully operational and consistently delivering power to the grid;
- Design, construction, supply and test in Galway Bay, Ireland, of an efficient and innovative impulse turbine for the Ocean Energy BBDB, in the context of the FP7 CORES project;
- Development of offshore modules for a new OWC concept, designed for cost effectiveness and compactness, expected to stand model tests in 2011.

EFACEC integrates the founding core of the new Institute of Offshore Renewable Energies as a means to integrate national and international wave energy technology. EFACEC owns (jointly with EDP and Pelamis Wave Power) the Aguçadoura wave energy demonstration site, which is a 4 MVA licensed grid connected demonstration site off the north coast of Portugal, approximately 5 km off the coast.

Sea for Life is a new Portuguese company that aims to develop and commercialize wave energy technology. It has in its premises a wave tank that is being used to test several new concepts to harness wave energy. Its new project – WEGA – Wave Energy Gravitational Absorber – is currently being developed by the company.

TECHNOLOGY DEMONSTRATION

The **400 kW Pico OWC** plant wave energy pilot plant on the Island of Pico, Azores, based on the oscillating water column (OWC) technology, has fed increasing amounts of electricity into the electrical grid, yielding more than 600 operational hours in 2010. It continues to be a platform of major significance for the technology learning process, R&D activities, training and dissemination.

Pico wave power plant, Azores

The Pico OWC was completed in 1999 with European funding but, due to a number of technical and financial difficulties, barely operated in the following years. In 2004, the Wave Energy Centre undertook a recovery project with national funding, and tests were initiated in the summer of 2005. Until 2010, it was not possible to obtain the required minimum funding for essential structural repairs that would valorize the potential of this plant, although its autonomous operation was demonstrated in a 2-week continuous test in March 2010. The building is designed to host a second turbo-generation group of the same size, which made it possible to be included in a European infrastructures network (MariNET) of large importance to the sector.

During 2010, **Generg** continued to develop actively the "Standpoint" project with its consortium partners Wavebob Ltd, Vatenfall AB, Hydac System GMBH, Wedge Global SL and Germanischer Lloyd Industrial Services GmbH. The "Standpoint" project consists in the deployment off the Portuguese coast of a concept demonstration, full scale, grid connected wave energy converter, based on technology developed in the last decade by Wavebob Ltd. The main activities carried on by Generg in 2010 relate to the definition of the deployment site. Apart from this project, Generg continued to participate in seminars at national and international level intended to raise awareness to the emergence of technologies related to the exploitation of wave energy and ocean energy in general.

Eneólica is actively participating in the demonstration and deployment of a new WaveRoller unit to be placed nearshore Peniche (100 km north of Lisbon) in the summer of 2011. ENEÓLICA is a member of the SURGE EU project.

REN, the concession holder of the national electricity transmission grid, has been appointed by the government as the manager of the Portuguese Wave Energy Pilot Zone. The Pilot Zone is a large area (320 km^2) located about 120 km north of Lisbon, available for the deployment of demonstration, pre-commercial and commercial wave energy plants and farms with a maximum capacity of 250 MW.

Denmark

Kim Nielsen / Ramboll

During 2010, Wave Star A/S was operating in the North Sea in Hanstholm, Dexa wave energy half-scale prototype was built and is ready to be tested at The Danish Wave Energy Center (DanWEC) established in Hanstholm. The Lindø Offshore Renewable Center (LORC) was founded and the organisation is operational, with the vision to establish a world-class R&D centre on future offshore renewable energy systems (presently mainly offshore-wind).

OCEAN ENERGY POLICY

Funding for wave energy projects in Denmark can be applied in competition with other renewable energy projects, via different national support programmes (table below).

The *E.U.D.P. Support Programme*, launched in 2008 under the Danish Energy Agency, can fund pre-commercial projects, and typically includes demonstration projects to help companies overcome the difficult phases toward becoming commercially viable.

R&D activities are funded via the *Public Service Obligation (PSO)* on the basis of tariffs charged for the transmission of electricity and natural gas in Denmark. Energinet.dk administrates the funds and wave energy R&D can be supported within two support strings:

- *ForskEL* – Supports R&D within environmentally friendly technologies for electricity generation.

- *ForskVE* – Supports projects with the purpose of spreading small renewable-technologies as photo voltage, wave-energy and biogas. Grid connection is required and each project can define a "feed-in tariff" as support for the project in the project period.

Million EUR	**2009**	**2010**
EUDP	39	40
The Danish Council for Strategic Research	23	40
R&D (PSO) ForskEL & ForskVE	21	21
The Danish National Advanced Technology Foundation	1	2
Total	84	116

The programmes cover all renewable energies and typically wave energy is supported with less then 5 % of these funds; The Danish Council for Strategic Research and the Danish National Advanced Technology Institute in addition cover non-energy projects.

RESEARCH & DEVELOPMENT

In 2010, two initiatives for wave energy development became operational: DanWEC, Danish test site for Wave Energy Conversion in Hanstholm, and LORC, Lindø Offshore Renewables Center, a science and development centre for offshore renewables.

Further, The Danish Council for Strategic Research granted Aalborg University, DTU, DHI and 11 other partners approximately € 3 million over a 5-year period for the research project "*Structural Design of Wave Energy Converters*" (SDWED), a strategic research alliance.

TECHNOLOGY DEMONSTRATION

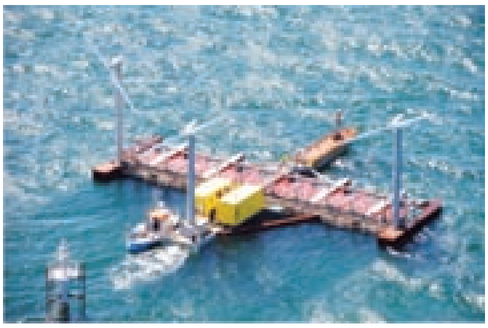
The wave energy technology projects being developed in Denmark are described below and summarised in the table below.

Wave Star Energy

A prototype section of the Wave Star converter was installed facing the North Sea on 7 m deep water connected to shore by Rosshage pier in Hanstholm, in September 2009. The section consists of two floats of 5 m diameter. The project has received funding from by EUDP, PSO and private investment. The local electricity company Thy-MorsEnergi is involved in the grid connection. Further, Wave Star Energy has a 1:10 scale demonstration version installed in Nissum Bredning.

Floating Power plant

Floating Power plant concluded the first test at sea in 2009 at the sheltered sea outside Vindeby. This was followed by a second test starting in the spring of 2010, including three wind turbines for testing the combination of wind and wave power. In parallel with open sea testing, R&D work in wave flumes is being carried out.



Wave Dragon

Wave Dragon was reinstalled in 2009 at the scale test site in Nissum Bredning (NB), the structure has an installed power of 20 kW. The purpose of the extended test is to gain as much data from the device as possible. Drifting ice at the sheltered site, in March 2010, caused problems and the test unit is presently (September 2010) not operating.

Waveplane

A prototype of the Waveplane wave energy converter was tugged to its position outside Hanstholm in March 2009. It was temporarily anchored overnight, but next day it stranded on the shore. Presently, Waveplane is located on shore waiting for additional investments to be launched again.

Dexa

Dexa wave energy converter has been built and tested in Nissum Bredning (NB) at 5 meter water depth. The device was installed in March 2009 and operated over a period of 10 months. During the winter, in February 2010, the device was removed due to problems with ice. A larger-scale model is built and being prepared for testing at DanWEC (Hanstholm). This system will be equipped with Hydraulic Power Take-Off (PTO) and measurement sensors, in order to monitor the loads on the mooring and performance of the device. The device will not be grid connected.

Leacon

A 1:10 scale model of the Leacon device is under construction and will be installed with one electrical generator and one pneumatic damper for power dissipation. The device installation has been delayed 12 months and it is now expected to take place in the spring of 2011 in Nissum Bredning.

Crestwing

The Danish floating wave energy converter "Crestwing" was tested at Aalborg University with positive results in 2009. In 2010, a design study was carried out including survival and performance testing at DHI to evaluate the costs of energy. Depending on the results the next phase could be the building of a prototype.

Technology	Phase of development	Installed Power	Public investment (M€)	Private investment (M€)
Wave Star Energy	Prototype testing	2*25 kW=50 kW	35	60
	1:10 testing NB	5.5 kW		
Floating Power plant	Prototype testing	140 kW	–	15
Wave Dragon	¼ scale prototype NB	20 kW	NA	
Waveplane	Prototype built not installed	2*100 kW=200 kW	0	18
Dexa	1:10 prototype NB – completed spring 2010	0,4 kW	0	1.7
	1:4 prototype DanWEC	20 kW	5	4
Leacon	1:10 model ready to Install in NB	1 – 2 kW	2.4	
Crestwing	Laboratory testing DHI	–	3	

(NB: Nissum Bredning)

United Kingdom

Alan Morgan, Department of Energy and Climate Change (DECC)

The new coalition Government recognises the potential and importance of marine energy by making support for marine energy an explicit part of the Coalition Agreement.

The Government is committed to harnessing the benefits which a successful marine renewables sector can bring to the UK and see the development of a UK Marine Energy Programme as being an important part of this.

DECC is working up the details but activities under the UK Marine Energy Programme could include, amongst other things:

- Providing assistance to the sector to accelerate private-sector development of pre-commercial arrays and commercial marine energy farms
- Establishing a collaborative Government/Sector "Marine Energy Programme Board" to identify, prioritise and address barriers to deployment
- Coordinating and influencing activity across government to support deployment of marine energy (e.g. availability of investment finance, marine spatial planning processes, supply chain availability, grid availability etc), and
- Facilitating sector-wide coordinating and information sharing

This will focus on addressing the priorities for action the sector has previously flagged, for example, in the Marine Energy Action Plan.

The Marine Energy Action Plan was a collaborative process between Government and industry to set out an agreed vision for the marine energy sector to 2030. The key recommendations from this Plan were published in March and will feed into future policy development. DECC and the Scottish Government undertook a study on the economics of wave and tidal energy in the UK and the results of the study were published in November.

A Strategic Environmental Assessment (SEA) for wave and tidal energy in English and Welsh waters is underway – as part of the UK Offshore Energy SEA – and should be completed in early 2011. An SEA for English and Welsh waters will complement the existing part SEA for Scotland and the SEAs prepared for the Severn estuary and Northern Ireland. This should open up the whole of UK waters for potential deployment of marine energy devices.

The Government has launched its scheduled Renewables Obligation (RO) banding review of all renewable technologies and has appointed independent consultants Arup and Ernst & Young to assess both the deployment potential and generation costs of renewable electricity technologies. It will consult on new banding proposals in the summer of 2011 and confirm the new bands by the autumn of 2011. The new bands will come into effect on 1 April 2013.

OCEAN ENERGY POLICY

Work is well under way on the marine energy infrastructure projects announced in last year's UK Renewable Energy Strategy. Up to £28 million is being invested in three projects at Wave Hub, EMEC and NaRE.

The pioneering Wave Hub marine energy project has been safely installed on the seabed, following a delicate operation to lower the 12-tonne hub into 55 metres of water, 16 kilometres offshore. Wave Hub is creating the world's largest test site for wave energy technology by building a grid-connected socket on the seabed off the coast of Cornwall in South West England, to which wave power devices can be connected and their performance evaluated.

Wave Hub marine energy project

There are four berths available at Wave Hub, each covering two square kilometres. Wave Hub will have an initial maximum capacity of 20 MW but has been designed with the potential to scale up to 50 MW in the future. The first wave energy devices are expected to be deployed in 2011.

The improvements and expansion to EMEC on Orkney continues apace. This project will provide three additional grid-connected berths (2 tidal, 1 wave) and four berths (2 tidal, 2 wave) non-grid-connected nursery sites in two locations. Each nursery site will have one fully configured berth with moorings available and a data and load dump buoy available (usable on either berth). The bare sites will allow developers, who want to test complete systems or just access moorings at the site, to do so. This gives EMEC maximum flexibility to offer the range of site facilities required by developers. The subsea cables for the grid-connected berths have successfully been laid and tested.

The new 3 MW marine drive train test rig "Nautilus" stand for NaREC is currently under construction and will be housed in a new purpose built building on the NaREC site in Blyth, Northumbria. The drive train is expected to begin commissioning in July/August 2011 and be ready for its first test slot in September 2011.

Devolved Administration:

Scotland

Scottish Government is working closely with partners in The Crown Estate and other public sector bodies to create opportunities in the form of leasing rounds for wave and tidal energy project. The Crown Estate has announced the names of the successful bidders for the world's first commercial wave and tidal leasing round, for eleven sites in Scotland's Pentland Firth and Orkney waters. 1.6 GW of installed capacity has been proposed by the wave and tidal energy developers for 2020, 1 GW for tidal and 600 MW for wave.

Northern Ireland

During 2010, the Department of Enterprise, Trade and Investment published a draft offshore renewable energy strategic action plan 2009-2020 for Northern Ireland (NI) waters, which was the subject of a strategic environmental assessment. The plan proposed a target of at least 300 MW of installed tidal stream by 2020. The Crown Estate is expected to launch a leasing round for NI waters in 2011 as a result of this work.

- The new Strategic Energy Framework 2010 sets out the over-arching energy policy for Northern Ireland, within which the draft Offshore Renewable Energy Strategic Action Plan has been developed. The Plan, which will be finalised in early 2011, contains a range of operational and legislative actions to support the development of the offshore renewable sector in NI waters.
- During 2010, the Department of the Environment consulted on proposals for a NI Marine Bill for devolved marine environmental issues and continued to work with the Department for Environment, Food and Rural Affairs (DEFRA). It is expected that the NI Marine Bill will be introduced to the NI Assembly for approval during 2011.

Wales

Wales continues to invest in the *Welsh Marine Renewable Energy Strategic Framework* (MRESF) that will ensure the optimum and sustainable energy extraction from the Welsh Sea with minimum environmental impact. Its aim is to understand the marine resources in Wales and the potential for development of all marine renewable technologies and also to help inform how they can be developed with minimal impact on marine eco-systems.

Wales is currently considering the availability of funds for port developments to assist in the deployment of offshore renewables and is examining a study to consider marine energy infrastructure requirements, including the possibility for a demonstration site.

Severn Tidal Power feasibility study

The two-year, cross-Government, Severn Tidal Power feasibility study was completed in March 2010 and the new coalition Government published its conclusions on 18 October – see www.decc.gov.uk/severntidalpower together with the 40+ detailed reports which make up the evidence base. The main conclusion of the study was that there is no strategic case for a publicly funded Severn tidal project at this time. The Government recognises that factors which will determine the feasibility of a tidal scheme in the Severn estuary could change over time. The report therefore includes potential triggers for a future review, though we do not envisage such a review before 2015. The conclusion of the study does not preclude a privately financed scheme coming forward and officials are liaising with several private sector consortia and individual companies about their ideas.

There has also been considerable activity outside the Severn, with feasibility studies completed for the Solway Firth and the Duddon estuary. Peel Holdings have recently published the Stage 2 report of their feasibility study for Mersey Tidal Power, which shortlisted four potential schemes. There are also proposals for a pilot land-connected tidal lagoon along the North Wales coast near Llandudno and for a tidal barrier on the Wash, on the east coast of England.

RESEARCH & DEVELOPMENT

The successful recipients of the £22 million Marine Renewable Proving Fund (MRPF) were announced in February. The six successful companies were Atlantis Resources, Aquamarine Power, Hammerfest Strom UK, Marine Current Turbines, Pelamis Wave Power and Voith Hydro. MRPF aims to accelerate the leading and most promising marine devices towards the point where they can qualify for the Government's existing Marine Renewables Deployment Fund (MRDF) support scheme and, ultimately, be deployed at a commercial scale under the standard Renewables Obligation.

Marine Renewables Proving Fund provides grant funding for the testing and demonstration of pre-commercial wave and tidal stream devices. The projects are aimed at deploying a pre-commercial device and obtaining the necessary operating data for entry into the MRDF (3 months continuous operation at full/commercial scale in real marine conditions). Four of the developers have deployed their devices in the sea with the remaining two developers to deploy in early 2011.

The Technology Strategy Board (TSB) launched two Wave & Tidal funding rounds during 2010, totalling £12 million. The first competition investing £9 million launched in March was targeted at reducing costs and improving performance. The second competition investing £3million was launched in September and is focused on underpinning deployment. Both competitions complement the MRPF and together they aim to advance development of wave and tidal technologies.

Devolved Administration:

Scotland

Scottish Government continues to support R&D activities at the world class European Marine Energy Centre (EMEC) on Orkney, where grid infrastructure, leased/consented seabed zones and expert research and operations staff combine to provide developers with excellent facilities in which to test devices and monitor the results and effects of generation in the marine environment. Scotland is also home to excellent academic marine research facilities and activity. Scottish universities (e.g., Edinburgh and Strathclyde) host tank test facilities and are active members of SUPERGEN marine research project.

The Scottish Government is funding a number of demonstration projects around Scotland, through its separate £13 million WATES and WATERS funds. While the latter announced its funding awards in July 2010, the former continues to support several projects and technologies, many installed or to be installed at EMEC.

Northern Ireland

Queen's University of Belfast (QUB) and the Ulster University continue to undertake research into renewable technologies.

Wales

The Assembly Government funded the Low Carbon Research Institute, which will co-ordinate research on clean energy technologies and their implementation in Wales. This research will include large-scale offshore wind and tidal power generation.

Sustainable Expansion of the Applied Coastal and Marine Sectors (SEACAMS) is a unique venture, the first to bring together some of the world's leading research expertise in marine, coastal and terrestrial environmental sciences.

TECHNOLOGY DEMONSTRATION

Aquamarine

Aquamarine deployed their Oyster 1 at EMEC in 2009. Oyster 1 is undergoing sea trials to gather data. The next-generation Oyster 2 is being fabricated by Burntisland Fabrications Ltd in Scotland and will be deployed at EMEC in the summer of 2011.

Pelamis

Pelamis Wave Power is currently manufacturing the 750 kW P2 Pelamis machine for energy utility, ScottishPower Renewables, the second utility to order a Pelamis machine in the UK. The Pelamis P2 machine is the second generation Pelamis wave energy converter. The first machine, purchased by E.ON was successfully connected to the grid for the first time in October this year (2010) and is now undergoing a staged programme of testing. E.ON and ScottishPower announced they will join forces in the trialling of their respective P2 devices. The two companies are developing 100 MW of Pelamis projects off the coast of Orkney and will use the information gathered from these trials to underpin larger commercial projects such as these.

Wavegen Limpet

Wavegen's Limpet plant on the Scottish island of Islay, marked its tenth anniversary this year and has clocked up over 60,000 grid connected generating hours. Commissioned in November 2000, the Limpet plant was the world's first commercial scale, grid connected wave energy plant. It now operates as a demonstration facility for new generation Wells turbines.

Atlantis

Atlantis successful deployed their AK 1000 (1MW) turbine at EMEC during August but suffered blade failure. Atlantis now starts a commissioning and operation programme that will last up to three years and the power generated from it will be dispatched into the local grid in Scotland.

Rolls Royce/Tidal Generation Ltd
Rolls Royce/Tidal Generation Ltd deployed their 500 kW turbine at EMEC Orkney in September and is currently undergoing sea trials and has generated electricity to the grid. RR/TGL have plans to deploy a 1 MW device in 2011, funded by the Energy Technologies Institute.

Marine Current Turbines
The Marine Current Turbines Tidal stream project " SEA GEN", the world's first commercial scale tidal stream project to connect to a national grid, continues to successfully generate and has so far delivered more than 2.3 GWh (as of November 2010) of electricity into the UK electricity grid. In addition, the device continues to deliver significant levels of environmental monitoring data on its operation.

Pulse Tidal
Pulse Tidal's 100 kW "Pulse Stream 100" was deployed in the Humber for testing in 2009 and is now generating electricity for Millennium Chemicals. It employs an "oscillating hydrofoil" device design. Pulse Tidal is developing a 1.2 MW device that it expects to be commissioned in 2012.

Neptune Renewable Energy Ltd
Neptune Renewable Energy Ltd successfully completed a series of rigorous in-water tests on a full-scale vertical axis tidal current demonstrator of its Proteus NP1000 tidal stream power generator. Tow testing was carried out in three phases during August, September and October in Hull's Albert Dock. The third set of experiments provided the final, critical, 'proof of concept' hurdle and means that the pioneering device will now be prepared for commercial deployment in early 2011 at Sammy's Point in the Humber. The electricity generated will be used to power The Deep Submarium to further develop its 'green-energy' operations.

Hammerfest Strom and **Voith Hydro** are expected to deploy MRPF funded tidal current devices at EMEC in early 2011.

Japan

Yasuyuki Ikegami, Saga University

OCEAN ENERGY POLICY

In July 2010, the new book "White Paper on Renewable Energy Technology" was issued by the New Energy and Industrial Technology Development Organization (NEDO), as an Executive Agency, in order to lead renewable energy development, and to contribute to government and industry investigation on improvement of international competitiveness and promotion of research on renewable energy. The book covers many kinds of renewable energy technologies, including ocean thermal renewable energy. Every kind of renewable energy technology roadmap for targeted goals is investigated in detail. NEDO has a crucial mission to carry out, as Japan's public management organization promoting research and development, as well as disseminating industrial, energy and environmental technologies.

In the wave power generation roadmap, the targeted goal is to develop the effectiveness of power devices in real conditions, in Japan, their international competitiveness, and also to train the domestic companies. The roadmap presents several technology issues to be solved, such as generating efficiency improvement, cost reduction, maintenance and damage preventing, marine environment protection, electric power transmission and stability of power output, etc. According to the roadmap, the target for R&D is to build a demonstration site at sea up to 2015. Up to 2020, the practical application of power generation in small-scale should be conducted with a unit power output of 0.5-1 MW, with a generation cost of about 20 JPY/kWh. Up to 2030, the unit power output should be 2 MW, with a targeted generation cost of about 5-10 JPY/kWh, in order to promote commercial operation of power generation in large-scale and the development of foreign markets.

In the ocean thermal energy conversion (OTEC) roadmap, the targeted goal is to maintain the technology leadership in the world and to train a new industry. The roadmap presents several technology issues to be solved, such as the promotion of R&D and demonstration test, the improvement of reliability, established core technology, etc. According to the roadmap, the target for R&D up to 2015 is that the demonstration test is expected to reach a unit power of about 1MW, with a targeted generation cost of about 40-60 JPY/kWh. Up to 2020, by the start of commercial operation of the power plant, the targeted generation cost of about 15-25 JPY/kWh is expected, as the unit power reaches about 10 MW. Up to 2030, when the power plant is operating at large-scale and the promotion of the development of foreign markets is in progress, the targeted generation cost of about 15-25 JPY/kWh is expected, as the unit power reaches about 50 MW.

On the ocean current and tidal current, many projects are being introduced in Japan, such as the development of the original 2MW ocean current electricity system. The roadmap to 2050 proposed by OEA-J (Ocean Energy Association – Japan) has been introduced in the book. According to the roadmap, it is expected that, up to 2020, the scale of ocean current and tidal electricity generation is about 130MW. Up to 2030, the scale is about 760MW. Up to 2050, the power generation scale is expected to reach 7600MW.

In March 2009, the Japanese government approved the "Ocean Energy/Mineral Resources Development Plan" based on the "Basic Plan on Ocean Policy" at the meeting of Headquarters for Ocean Policy (Director-General: Prime Minister), and opened it to the public. The main contents concern investigation and technology development for the implementation of methane hydrate and seafloor massive sulfide deposit (Roadmaps). However, Ocean Renewable Energy is not mentioned. Meanwhile, in 2010, the Japanese government considered the promotion of ocean renewable energy to the next stage of R&D.

Ireland

Eoin Sweeney, Sustainable Energy Authority of Ireland (SEAI)

OCEAN ENERGY POLICY

In 2006, the Irish Marine Institute and Sustainable Energy Ireland prepared a National Strategy for Ocean Energy. This phased strategy aims (a) to introduce ocean energy into the renewables portfolio in Ireland and (b) to develop an ocean energy sector. It aims to support national developers of wave energy devices through concept validation, model design optimisation and scale model testing and deployment.

- Phase 1 (2005-2007): an offshore test site for 1:4 scale prototypes was developed in Galway Bay, research capabilities were enhanced and some funding was provided from a variety of sources to researchers and developers.
- Phase 2 (2008-2010): development of a grid-connected test site continued during 2010 and will commence operation phase 3.
- Phase 3 (2011-2015): will involve pre-commercial small array testing and evaluation over a sustained period.
- Phase 4 (2016-ongoing): will involve development of strategies for commercial deployment of wave power technologies.

The strategic context of the programme changed in 2007/8 with targets for the use of ocean energy in Ireland, as announced by the Government in the White Paper and the Programme for Government, increased to 500 MW by 2020. To achieve these objectives, the Government provided an initial 3-year (2008-2010) financial package of c. € 27 million, to be administered by a new Ocean Energy Development Unit (OEDU), based within the Sustainable Energy Authority of Ireland (SEAI).

The 2010 financial allocation covered:

- Support for device developers
- Enhancement of the test facilities at the Hydraulics and Maritime Research Centre (HMRC), University College Cork
- Development of grid-connected test facilities
- Undertaking a Strategic Environmental Assessment for offshore wind, wave and tidal energy in all Irish coastal waters
- Commissioning of work in the areas of economics, and supply chain

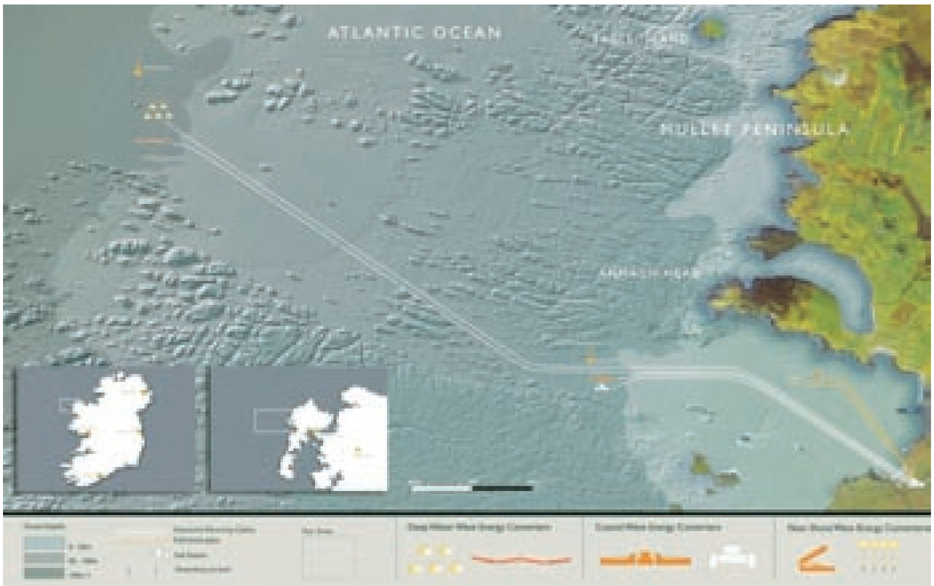
The policy support package for wave and tidal energy includes a commitment of a feed-in tariff of € 0.22/kWh for electricity produced from wave and tidal devices, guaranteed up to 2030.

Implementation of Ireland's Ocean Energy Strategy continued in 2010. The Strategic Environmental Assessment process for offshore wind, wave and tidal energy developments in Irish waters was completed and legislation to establish a new planning system will follow in early 2011. Work continues on the establishment of a Phase 5 wave test facility. The funding mechanism for industry saw the successful completion of several part-funded projects and continues to support new projects. Studies on the economics of ocean energy and supply-chain and infrastructure issues associated with the development of ocean energy projects were completed.

The national Transmission System Operator (TSO), Eirgrid, is accelerating and intensifying work on the design and planning of offshore grid and work has commenced on a 500MW interconnector between Ireland and the UK. The Department of Energy and the TSO actively participate in the work of the North Seas Offshore Grid Initiative.

The Atlantic Marine Energy Test Site

The proposed layout of the Atlantic Marine Energy Test Site (AMETS), in Belmullet off NW Ireland, is presented in the picture below.



RESEARCH & DEVELOPMENT

An R&D funding scheme for industry-led projects to develop wave and tidal technology continues in place and covers:

- Industry-led projects to develop and test wave and tidal energy capture devices and systems;
- Independent monitoring of projects/technologies;
- Industry-led R&D aimed at the integration of ocean energy into the electricity market and the national electricity grid (and network);
- Data monitoring, forecasting, communications and control of ocean energy (OE) systems;
- Specific industry-led research projects which will be carried out by research centres, third level institutions and centres of excellence with a high level of expertise in the relevant area.

Since its inception in 2009, over € 4.9 million have been committed by OEDU to 18 industry-led projects with a total value over € 11 million. Other public sector funding of industry-led OE R&D in 2009 is estimated at € 1.2 million.

Other relevant R&D information includes:

Hydraulics and Maritime Research Centre in University College Cork is a key ocean energy research facility in Ireland with special interest in ocean energy research and coastal engineering. The group expanded its staff size in 2007, following the allocation of long-term funding of research personnel from the Parson Energy Research awards, administered by Science Foundation Ireland. It is currently upgrading its equipment and facilities with financial support from the OEDU and further major enhancement of the facility as the National Ocean Test Facility is planned, with financial support from the Higher Education Authority, industry and the OEDU. Key areas of research expertise include:

- Ocean Energy Resource assessment
- Wave Energy Physical Device model testing
- Field Testing and Measurements – Wave, Tidal, Coastal
- Computational Fluid Dynamics – Wave & Tidal
- Numerical Modelling, Wave, Tidal & Coastal processes
- Analytical Modelling , Wave, Tidal & Coastal processes
- Electrical, Power Electronics and Control Systems
- Instrumentation and Data acquisition
- PTO – Turbomachines & Hydraulics
- Economic Modelling
- Environment and Marine Law

The European Commission funded CORES (Components for Ocean Renewable Energy Systems) project is being coordinated by Hydraulic and Marine Research Centre (HMRC) in Ireland with partners from Portugal, Spain, UK, Ireland, Germany, Denmark and Italy. This project is researching new systems and components for floating oscillating water column systems. The Ocean Energy Ltd. OE Buoy is being used as the test platform with a novel air turbine developed in Portugal, and the electrical control system jointly developed in Ireland, Germany and Spain. The data acquisition and telemetry is being developed in the UK and Ireland with a novel mooring force measurement system being developed in the UK.

All of the test components are being shipped to Galway for fit-out on the OE Buoy hull and the device will be deployed during the first quarter of 2011. Testing and monitoring will continue in the first quarter of 2011 at the Galway Bay Test Site and the data will be used to verify mooring force and power performance numerical models under development in Ireland and Portugal.

University of Limerick has been actively pursuing the development of air turbines for use with oscillating water column devices.

The Electricity Research Centre in University College, Dublin, has had significant involvement in the integration and the study of management issues for intermittent renewable generators such as wind power systems operating on the national grid. Their interests include modelling of dynamic response of electrical generators and tidal energy systems.

The Department of Electronic Engineering in the National University of Ireland, Maynooth, has a dedicated group working in the areas of:

- Hydrodynamic modelling
- PTO modelling
- Impact of wave directionality on wave energy converters (WECs)
- Device optimisation
- Control system design for WECs
- Resource assessment and forecasting

The Department of Electronic Engineering, Maynooth University, has a group working on control systems and device optimisation.

TECHNOLOGY DEMONSTRATION

No new ocean energy projects commenced during 2010. Scoping and planning studies are underway for a number of proposed deployment and demonstration projects.

Canada

Melanie Nadeau and Tracey Kutney, CanmetENERGY, Natural Resources Canada

The development of clean, affordable and environmentally sustainable electricity generation is part of the Government of Canada's priorities. With the longest coastline in the world and a legacy of hydropower, ocean engineering and offshore expertise, there is considerable promise for marine renewable energy in Canada. In 2010, the Government of Canada announced a significant contribution to the demonstration of tidal technologies at the Fundy Ocean Research Centre for Energy (FORCE) located in the Bay of Fundy in Nova Scotia. To date, federal and provincial governments have invested over $60 million (CAD) towards the demonstration of wave, tidal and hydrokinetic technologies.

Within the research community, expertise has been developing in the areas of resource assessment and modelling, device deployment and operation, as well as environmental assessment and monitoring. Discussions have commenced around the permitting requirements and legal framework for larger projects consisting of arrays.

OCEAN ENERGY POLICY

The Government of Canada is committed to reducing Canada's total greenhouse gas emissions by 17 per cent from 2005 levels by 2020 – a target that is inscribed in the Copenhagen Accord and aligned with the United States. To meet this commitment, the Government has been implementing regulations to reduce greenhouse gas emissions in the transportation sector, has introduced new regulations on coal-fired electricity generation and announced funding in the 2010 budget to advance clean energy technologies in the forestry sector. Whilst there remains continued interest in offshore renewables, no directed policies addressing renewable energy or ocean energy were announced in 2010. Support programmes administered by Natural Resources Canada (NRCan), including the Clean Energy Fund, the programme for Energy Research and Development, and the ecoEnergy Technology Initiative, continue to be the main source of financing for national research, development, and demonstrations. To date, over $28 million (CAD) have been committed to marine renewable energy research, development and demonstration (RD&D). In addition, Sustainable Development Technology Canada (SDTC), an arm's length foundation created by the Government of Canada, has committed approximately $20 million (CAD) to develop and demonstrate projects that include tidal, wave and low head hydro technologies.

In early 2009, NRCan held a federal/provincial workshop to discuss options for a legal framework for permitting of offshore renewable energy in Canada. In November 2010, as a follow-up to the 2009 consultations and as an extension of Nova Scotia's consultations on marine renewable energy legislation, NRCan hosted another federal/provincial workshop related to environmental and regulatory issues.

In late 2010, Fisheries and Oceans Canada (DFO) initiated the development of a strategy to support an efficient regulatory framework for ocean renewable and clean energy initiatives. The intent of this study is to identify future information needs related to the granting of project approvals for the construction, operation and decommissioning of offshore renewable energy (wind, wave and tidal) devices in Canada marine and aquatic ecosystems. This initiative will also define best practices (approaches) for environmental monitoring, as well as outline the requirements for an efficient permitting process.

A Marine Renewable Energy Technology Roadmap has been launched by NRCan to provide a clear strategic vision to Canada's participation and key capabilities to support and move the marine renewable industry towards commercialization. The roadmapping process will engage industry as well as industry stakeholders through a series of workshops commencing in early 2011. The roadmap exercise is led by Nova Scotia Power Inc. and guided by a Steering Committee, consisting of representatives from various industry sectors and government.

Provincial governments have become increasingly active in promoting the development of emerging renewable energy, such as marine energy. Notably, the Province of Nova Scotia has been working on developing long-term regulatory measures to support early adoption of tidal current energy in the Bay of Fundy. Their Renewable Electricity Plan, released in 2010, mandates 25 per cent renewable electricity by 2015 and 40 per cent by 2020. Feed-in tariffs for small and large scale tidal projects and arrays are currently being discussed. To date, the province has committed approximately $7.5 million (CAD) to tidal energy RD&D in the Bay of Fundy.

On the western coast, British Columbia (BC) is finalizing their policy directive for occupational licenses for offshore renewable energy projects. In BC's Clean Energy Act, announced in mid-2010, the Province committed to developing support mechanisms (i.e., a feed-in tariff) for emerging technologies such as ocean energy. The BC Government has also announced over $6 mill ion (CAD) to wave and tidal current projects under their Innovative Clean Energy fund.

RESEARCH & DEVELOPMENT

Several federal government institutions are engaged in conducting research and development related to advancing marine energy technologies in Canada. These organizations include:

- CanmetENERGY, NRCan
- Geological Survey of Canada, NRCan
- Institute for Ocean Technology, National Research Council (NRC)
- Canadian Hydraulic Centre, NRC
- Bedford Institute of Oceanography, DFO
- Centre for Offshore Oil, Gas and Energy Research, DFO

Below are some of the highlighted research areas/projects that are led by these organizations in collaboration with industry:

- Assessment of hydrokinetic resources
- Development and model testing of a large scale procedure for deployment of a tidal turbine
- Development of mooring systems for wave and tidal energy converter deployments

- Development of standards for marine energy conversion systems
- Wave energy resource characterization and forecasting on the Canadian west coast
- Optimization of electrical generation and interconnection subsystems for hydrokinetic technologies
- Integrated seabed suitability assessment for marine energy development
- Identification of geohazard barriers to extensive marine energy deployment
- Development of numerical models to evaluate and optimize farm array orientations

Regionally, there is on-going research and development being administered by Nova Scotia's Offshore Energy and Environmental Research (OEER) Association. This research is being completed by representatives from academia and federal research institutions. The research areas addressed include:

- Assessment of the potential of tidal power from Minas Passage & Minas Basin
- Assessing the far field effects of tidal power extraction in the Bay of Fundy, Gulf of Maine & Scotia Shelf
- Effects of energy extraction on sediment dynamics in intertidal ecosystems of the Minas Basin
- 3-D acoustic tracking of fish, sediment-laden ice and large debris in the Minas Channel of the Bay of Fundy
- Investigation of the vertical distribution, movement and abundance of fish in the vicinity of proposed tidal power energy conversion devices
- Hydrodynamic impacts of tidal lagoons

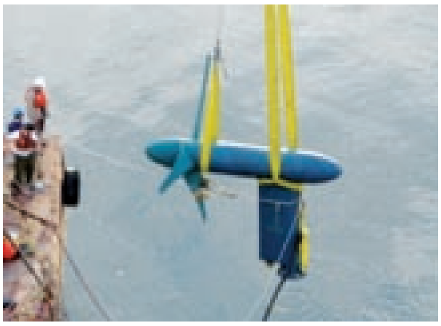
Beyond these activities, there has been on-going tank testing of devices at the National Research Council's Institute for Ocean Technology and Canadian Hydraulic Centre.

TECHNOLOGY DEMONSTRATION

Nova Scotia Power Inc, in partnership with the Irish company OpenHydro, deployed a 1 MW turbine in the Bay of Fundy in November 2009 at the Fundy Ocean Research Centre for Energy (FORCE). The 10-metre diameter turbine is the first commercial-scale turbine deployed in North America. OpenHydro intends to recover the turbine for a complete engineering analysis and redeploy in 2011.

Renewable Energy Research, a subsidiary of Groupe RSW, deployed their 250 kW TREK technology (Kinetic Energy Recovery Turbine) in the St. Lawrence river, near the Old Power of Montreal, Quebec.

Verdant Power Canada is working on the deployment of their horizontal axis turbine in the St. Lawrence River. Verdant is in the process of obtaining permits to deploy an ACDP to conduct some baseline monitoring. The company plans to deploy their technology in the spring of 2011.



The Canoe Pass Tidal Energy Consortium (New Energy Corporation Inc., Canoe Pass Tidal Energy Corporation and the City of Campbell River) is in the process of obtaining permits to develop a commercial tidal energy site at Canoe Pass in British Columbia. The project will involve the removal of a causeway, restoration of the tidal flow and installation of a mechanical span across the pass for two 250 kW turbines. New Energy Corp has already installed over nine vertical axis 5 kW and 25 kW turbines in river systems.

Fundy Ocean Research Centre for Energy (FORCE)
FORCE is Canada's research centre for in-stream tidal energy, located in the Bay of Fundy, Nova Scotia. FORCE is a non-profit institute that owns and operates a facility where grid connected tidal energy turbines can be tested and demonstrated. It enables developers, regulators, scientists and academics to study the performance and interaction of tidal energy turbines with the environment. To date, three berths have been committed and a fourth berth was proposed in a request for expressions of interest in the fall of 2010. The fourth berth holder has yet to be finalized. The four cables for the site should be installed in late summer 2011. Although there are only 4 devices planned for testing at this time, each cable will have a capacity for 16 MW, providing opportunities for future expansion of the facility.

United States of America

Alejandro Moreno, U.S. Department of Energy

This past year has seen an impressive number of developments for ocean energy technology in the United States. While no major pieces of renewable energy or climate change legislation were enacted, environmental and technology research for ocean energy has continued to increase and expand with substantial government support. Significant scientific programmes continue to develop at multiple universities and national laboratories, and several commercial wave and tidal energy projects are soon expected to submit applications for federal operating licenses. The outlook for 2011 is also optimistic, with indications that government support will continue at stable or increasing levels, and results from a number of various research projects will soon be available.

OCEAN ENERGY POLICY

The year 2010 saw significant changes to Unites States national ocean policy and to the structure of one of the major regulatory agencies governing ocean energy. In July, President Obama signed an Executive Order establishing a new national ocean policy and creating a new National Ocean Council charged with implementing this policy. The National Ocean Council will oversee the formation of regional Coastal and Marine Spatial Plans (CMSP) for the nation. United States ocean energy developers have expressed some concern that the development of coastal and marine spatial plans could both delay development and limit the geographic areas in which development is allowed. However, there is also hope that baseline data collection on site suitability could ultimately lead to increased siting efficiency for renewable ocean energy.

Following the Deepwater Horizon oil spill in the Gulf of Mexico, the federal agency responsible for offshore energy regulation on the Outer Continental Shelf of the United States, the Department of the Interior agency, Minerals Management Service, was restructured and renamed the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE). Internal restructuring within BOEMRE is ongoing and may affect the regulation of ocean renewable energy on the Outer Continental Shelf.

Although the U.S. has not yet passed the Fiscal Year 2011 appropriations bill, both the House and Senate appropriations marks currently include $50-$60 million allocated for the Department of Energy's water power research efforts. Such appropriation levels indicate strong, continued support for MHK research and development. During 2010, both the House and the Senate introduced major energy bills and climate bills. However, as the end of this Congressional term nears, neither bill has been passed.

Within the U.S. Federal government, there is a continued emphasis on inter-agency collaboration surrounding the development and deployment of MHK technologies. This spring, DOE and the Department of the Interior signed a

Memorandum of Understanding (MOU), agreeing to collaborate to advance the coordinated deployment of offshore wind and marine and hydrokinetic energy technologies on the US Outer Continental Shelf. Additionally, the Federal Energy Regulatory Commission (FERC) signed an MOU with the State of California in 2010 for the coordinated authorization of hydrokinetic projects. This MOU is the latest in the series that FERC has signed with a number of coastal states including Oregon, Washington and Maine.

RESEARCH & DEVELOPMENT

The primary focus of Federal-level activity remains the provision of grant support to companies and institutions active in ocean energy R&D in the United States – much of which is funded through the DOE Wind & Water Power Technologies Program.

Department of Energy Marine and Hydrokinetic Technology Readiness Advancement Initiative

On 9 September 2010, DOE announced selections for more than $37 million in funding over three years to accelerate the technological and commercial readiness of MHK technologies. Twenty-seven cost-shared projects were funded under this solicitation, ranging from concept studies and component design research to prototype development and in-water device testing. This solicitation was structured to advance technology maturity through Technology Readiness Levels, or TRLs. Technology readiness and associated TRLs are used by numerous Federal agencies, including the Department of Defense and National Aeronautics and Space Administration, and many private sector companies, as a measure (or metric) to assess the maturity of evolving technologies.

This solicitation represents the single largest investment in U.S. history in the MHK sector. Using TRLs as an organizing principle reduces risk within DOE's investment portfolio and allows tracking of progress towards technology maturity. Funding this solicitation will allow for the deployment of three full-scale demonstration projects over the next two years (described below in Technology Demonstration). The level of response to the solicitation across all technology readiness levels demonstrated significant increase in activity in the MHK industry.

More information: http://www.eere.energy.gov/pdfs/project_selections_mhk_release.pdf

Small Business Innovation Research Programme

Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) are U.S. Government programmes in which Federal agencies, with large research and development budgets, set aside a small fraction of their funding for competitions among small businesses only. Small businesses that win awards in these programmes keep the rights to any technology developed and are encouraged to commercialize the technology. In 2010, the Department of Energy SBIR/STTR programmes made 20 Advanced Water Power Technology Development awards. Funded topics included advanced design and manufacturing technologies for composite materials, advanced technologies for wave energy conversion, conceptual design and modelling for ocean thermal energy conversion, advanced power converters and power take-off mechanism development. Awards ranged from up to $100,000 for Phase I awards and up to $750,000 for phase II awards.

More information: http://sbir.er.doe.gov/sbir/Awards.html

Broad Agency Announcement for Environmental Research and Monitoring for MHK

Through a competitive joint funding opportunity known as a Broad Agency Announcement (BAA), BOEMRE, DOE and the National Oceanographic and Atmospheric Administration (NOAA) solicited and selected nearly $5 million in research projects under six topic areas to address immediate and long-term environmental information needs of both the offshore wind and marine and hydrokinetic industries. This innovative partnership will help to ensure that U.S. environmental research is targeted to meet key regulatory needs and significantly magnify the impact of the research funded by all three agencies on the reduction of environmental risks.

Funding under this solicitation is broken down under the following topic areas:

- Characterization & Potential Impacts of Noise Producing Construction & Operation Activities on the Outer Continental Shelf.
- Protocols for Baseline Studies and Monitoring for Ocean Renewable Energy. Evaluation of Environmental Monitoring Technologies for Offshore Renewable Energy.
- Sub-Seabed Geologic Carbon Dioxide Sequestration Best Management Practices.
- Renewable Energy Visual Evaluations.
- Ocean Renewable Energy Siting in the Context of Coastal and Marine Spatial Planning.

More information: http://www.nopp.org/funded-projects/fy2010-projects/

Designation of Florida Atlantic University as Southeast Marine Renewable Energy Center

On 3 August 2010, DOE awarded $250,000 to the Center for Ocean Energy Technology at Florida Atlantic University to launch the Southeast National Marine Renewable Energy Center. The newest national center for ocean energy research and development joins existing centers in the Pacific Northwest and Hawaii that also research and test ocean energy technologies. The university's location near the Florida Straits and Gulf Stream, and its proximity to the ocean, allows the new center to research sustainable, renewable energy technologies capable of generating energy from ocean currents and ocean thermal energy. In addition, the research facility will collaborate with industry partners to investigate next-generation water power technologies. Researchers have already begun deploying ocean current observation systems to establish environmental baselines. The center will ultimately perform full-scale field testing of prototype devices.

TECHNOLOGY DEMONSTRATION

As described above in "Research and Development", in 2010, DOE provided support for industry demonstration projects through its Technology Advancement Initiative. The Initiative funded 27 different projects, including:

- **Ocean Power Technologies, Inc.** (Pennington, New Jersey) will deploy a full-scale 150 kilowatt PowerBuoy system in the Oregon Territorial Sea and collect two years of detailed operating data. This project will obtain critical technical and cost performance data for one of the most advanced wave energy converters in the U.S. DOE Funding: $2,400,000. Total Project Value: $4,800,000.

- **Ocean Renewable Power Company** (Portland, Maine) will build, install, operate, and monitor a commercial-scale array of five grid-connected TidGen™ project devices on the sea floor in Cobscook Bay off Eastport, Maine, in two phases over three years. The project will advance ORPC's cross-flow turbine tidal energy technology, producing a full-scale, grid-connected energy system and will gather critical technical and cost performance data for one of the most advanced tidal energy systems in the U.S. The completed project will comprise an array of interconnected TidGen™ hydrokinetic energy conversion devices, associated power electronics, and interconnection equipment into a system fully capable of commercial operation in moderate to high velocity tidal currents in water depths of up to 150 feet. The project will significantly advance the technical, operational and environmental goals of the tidal energy industry at large. DOE Funding: $10,000,000. Total Project Value: $21,100,000.

- **Public Utility District No.1 of Snohomish County** (Everett, Washington) will deploy, operate, monitor, and evaluate two 10-meter diameter Open-Centre Turbines, developed and manufactured by OpenHydro Group Ltd., in Admiralty Inlet of Puget Sound. The project is expected to generate 1 megawatt (MW) of electrical energy during periods of peak tidal currents with an average energy output of approximately 100 kilowatts (kW). This full-scale, grid-connected tidal turbine system will gather critical technical and cost performance data for one of the most advanced tidal turbine projects in the U.S. DOE Funding: $10,000,000. Total Project Value: $20,100,000.

In addition to these, the U.S. MHK industry continues to refine and demonstrate technologies in domestic markets and abroad:

- **Tidal Power provider Verdant Power** signed a Memorandum of Understanding with the China Energy Conservation Environment Protection Group to develop a tidal energy project in China. Verdant continues plans to build out projects in New York's East River, in Ontario's Saint Lawrence River, and in Washington State's Puget Sound in partnership with the U.S. Navy.

Current Navy Activity:

The U.S. Navy has received congressional funding to pursue open-water testing of a tidal current device in the Puget Sound. They have completed some initial site surveys, have undertaken preliminary design of a tidal current test platform, and are currently working through the permitting process for the platform. They intend to deploy a device for 1 year to monitor performance and environmental effects. In addition, the U.S Navy has continued testing of a sub-scale wave energy converter in Hawaii.

FOA000069 Demonstration Project Progress:
In FY09, DOE solicited applications for projects in the following areas:

- Marine and Hydrokinetic Energy Conversion Device or Component Design and Development
- Marine and Hydrokinetic Site-specific Environmental Studies/Information
- Advanced Water Power Market Acceleration Projects/Analysis and Assessments

There were multiple demonstration projects awarded under this solicitation with results expected in 2012. During the last year, these projects navigated many of the permitting requirements and moved closer to device deployment.

Test Center Activity:
Oregon State University (OSU) and University of Washington (UW) in partnership are developing the *Northwest National Marine Renewable Energy Center* (*NNMREC*) with a full range of capabilities to support wave and tidal energy development for the United States. During this year, NNMREC has made strides in test berth design and permitting, community outreach and education, expanding evaluation capabilities for anti-fouling research, characterizing both wave and tidal energy testing sites, developing Marine Biofouling Resistant Materials, enhancing acoustic monitoring and acoustic deterrence capabilities.

Hawaii's National Marine Renewable Energy Center (HINMREC) was established in 2008 to facilitate commercialization of Wave Energy Conversion (WEC) devices and to accelerate development and testing of Ocean Thermal Energy Conversion (OTEC) technologies. HINMREC supports design of OTEC pre-commercial plants and plans to provide WEC developers access to grid connected berths under a variety of ocean conditions. This year, efforts have focused on environmental impact studies/permitting, wave resource characterization and forecasting, modelling of energy conversion devices, grid modelling, corrosion and biofouling. Test facility development was focused on 4 distinct sites to accommodate WEC and OTEC testing. One of the sites also leverages US Department of Defence (DOD) interest in ocean energy projects.

Industry Progress:
Ocean Power Technologies, Inc. signed a ground-breaking Settlement Agreement (SA) with 11 federal and state agencies and three non-governmental stakeholders for its utility-scale wave power project in Reedsport, Oregon. This agreement represents a major step towards the grant of the first license ever issued by the Federal Energy Regulatory Commission (FERC) for a commercial-scale wave power project in the US. The SA supports the responsible, phased development by OPT of a 10-buoy PowerBuoy, 1.5 megawatt capacity wave energy station in a manner that protects ocean resources and stakeholder interests. Manufacturing of the first 150 kilowatt PB150 PowerBuoy is already underway at Oregon Iron Works under its contract with OPT. The 10-buoy wave farm is expected to be connected to the grid after receipt of the FERC license and additional funding, supplying clean energy to approximately 1,000 homes.

Belgium

Pieter Mathys, Ghent University

OCEAN ENERGY POLICY

The Flemish government voted a decree to support electricity production from renewables (July 2009). It guarantees a price of € 90/MWh for a Tradable Green Certificate for wave or tidal energy, guaranteed for a period of 10 years. No new initiatives were taken in 2010.

RESEARCH & DEVELOPMENT

The Agency for Innovation by Science and Technology (www.iwt.be) approved the funding of € 2.4 million in September 2010 for the FlanSea (Flanders Electricity at Sea) project. The aim is to develop a point absorber buoy which is suitable for moderate wave climates, building on the expertise that was acquired in the Sustainable Economically Efficient Wave Energy Converter (SEEWEC) project and previous PhD and Master dissertations. In the first 2 years, a buoy will be developed and assembled, which will be tested in the third year. The project consortium consists of 4 research groups of the Ghent University (coastal, material, maritime and electrical engineering), DEME Bleu Energy (a subsidiary of the dredging and hydraulic engineering group DEME); Cloostermans (an innovative SME specialized in machinery); Electrawinds (a producer of renewable energy); Harbour of Ostend and Contec (an SME specialized in process control and industrial automation).

The Belgian Science Policy (BELSPO) has funded 2 projects regarding offshore energy. The results of the first project, OPTIEP-BCP, were presented in a workshop in April 2010. The full report (in Dutch, but with French and English executive summaries) can be downloaded at:

http://www.belspo.be/belspo/home/publ/pub_ostc/AP/rAP42_nl.pdf

The second project (BOREAS or Belgian Ocean Energy Assessment) will assess the wave and tidal energy climate in detail and is ongoing. The final report is expected in the second quarter of 2011.

Germany

Jochen Bard, Fraunhofer Institute for Wind Energy and Energy Systems Technology IWES

OCEAN ENERGY POLICY

Germany's Federal Government committed itself to cut its greenhouse gas emission by 40 % compared to the 1990 baseline levels by 2020, if the European Union Member States agree to a 30 % reduction of European emissions over the same period of time. A comprehensive National "Integrated Energy and Climate Programme" has the potential to bring Germany very close to this goal by achieving a reduction of at least 36 % according to independent studies. Key elements of this programme are amongst others:

- Renewable Energy Sources Act with the goal to increase the share of renewables in the electricity sector from the current level of at least 14% to 25-30% in 2020
- Amendment to the Combined Heat and Power Act with the goal to double the share of high-efficiency Combined Heat and Power (CHP) plants in electricity production by 2020 from the current level of around 12% to around 25%
- Renewable Energies Heat Act with the goal to increase the share of renewable energies in heat provision to 14% by 2020.
- Actions for grid expansion in a package of measures to improve the integration of renewables into the grid. The Energy Grid Expansion Act includes a bundled approval procedure for undersea cables connecting offshore wind turbines when new grid construction is undertaken. (IECP Action 2)
- Several actions towards energy saving in the transport and building sectors

In context with the amendment of the Renewable Energy Sources Act, a new regulation on the demarcation of areas for specific uses at sea within the German exclusive economic zone (EEZ) of the North and Baltic sea, in particular offshore wind energy, came into force in 2009. It reflects the government strategy for offshore wind energy which aims for the installation of wind turbines with a combined capacity of up to 25,000 MW by 2030. Spatial planning includes the designation of priority areas. The legal impact of this status is that any other uses that are not compatible with the designated priority must be disallowed or denied authorisation, thereby ring-fencing potential locations for offshore wind farms. To permit a flexible response to research that remains to be conducted on offshore wind energy use, these demarcations will initially only secure locations for a first tranche (with a total capacity of approx. 10,000 MW). A decision will have to be taken in the medium term as to whether any further priority areas are to be designated and, if so, where, on the basis of an amended or new plan, so that the government's target of 25,000 MW can be assigned within the appropriate corridor.

Currently, there are no explicit plans to include wave energy into spatial planning but a study launched by the National Government identified no issues in the legislation which would prevent wave energy projects from receiving approval.

A feed-in tariff for electricity from wave and tidal energy similar to the tariff for small hydropower has been available under the Renewable Energy Act since 2005. These figures were raised in 2009 to € 11.67/kWh for power plants below 500 kW and € 0.0865/kWh up to 5 MW.

The results from the national study on the German ocean energy resources, grid integration aspects and synergies with offshore wind were discussed in an experts hearing in March 2010. The study is currently undergoing internal approval procedures.

RESEARCH & DEVELOPMENT

The first German offshore wind park Alpha Ventus was completed in 2009. Alongside the installation and operation of these 12 turbines (rated at 5 MW each), the research programme RAVE has been launched. RAVE funds 14 projects with a total budget of around € 50 million covering topics around the operation and monitoring, foundation and support structures, turbine technology, grid integration and ecology and safety. This project is the start of the exploitation of the German offshore wind resources. See for details http://www.rave-offshore.de

In the ocean energy 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 € 150 million in 2008. This programme is open to ocean energy research but not many proposals have been funded yet. Up to now, three technology projects related to the development of components and concepts for tidal turbines have been funded for a total amount of € 5.4 million.

The first projects were related to the development of a tidal turbine concept and component. Fraunhofer IWES (former ISET) and LTI Power Systems developed a pitch system, the dynamic simulation, control engineering and new drive train concepts for marine current turbines, such as the British Seagen concept, which was successfully installed in 2008.

In 2009, another project was launched by Voith Hydro in cooperation with Loher for the development of a tidal turbine concept. It is based on a fully submerged horizontal turbine equipped with a variable speed direct drive permanent magnet generator and symmetrically shaped fixed blades which allow the operation in two opposite flow directions. A first 110 kW pilot installation is currently ongoing at a site off the coast of South Korea. A second device is planned to be installed at the European Marine Energy Centre (EMEC) for testing with funding from the UK Marine Renewables Proving Fund (MRPF). In February 2009, Voith Hydro, together with the German utility RWE Innogy, founded a joint venture named "Voith Hydro Ocean Current Technologies". In the framework of its venture capital activities, RWE holds 20% of the shares. The total investment expected in the coming years to commercialise the turbine technologies is € 30 million.

In 2005, Voith Hydro acquired the Scottish company Wavegen. Under the leadership of Voith, Wavegens's Wells-turbine technology has been further developed. Another breakwater installation is planned on the Isle of Lewis. Other German suppliers such as Siemens, Bosch Rexroth, Schaeffler, Contitech, Thyssen Krupp 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 and consultants are contributing to the technology and project development in the sector. This international collaboration demonstrates the technology export opportunities which exist in the ocean energy for the German industry.

Three major German utilities (EON, Vattenfall and RWE) are active in the OE sector with test installations and prototypes around Europe. There is no ocean energy installation realised in Germany yet and no plans for installations have been published this year.

A new strategic initiative statement towards OE has been prepared involving R&D and industry associations from the maritime technology, as well as the engineering industry sectors.

At present, a National Master Plan Maritime Technologies is being prepared under the coordination of the Ministry of Economics and Technology to support the development of the maritime technology industry in the coming years. The goal is to develop recommendations for a future coordinated maritime technology policy, at federal and state level, and the clustering of the core competencies of industry and science through enhanced networking and clustering. A study on the preparation of the National Master Plan Maritime Technologies and potential of the German maritime technology industry in international competition has been announced by the Federal Ministry of Economics and has been contracted. It is anticipated that ocean energy technologies will play a prominent role in the plan.

Norway

Harald Rikheim, Statkraft Development AS

Due to the attractive energy resource and pragmatic consenting process for small scale test installations in the sea several developers continue their development work in Norwegian waters. The academic R&D activity also remains strong in all aspects of ocean energy. Governmental support and encouragement for R&D is increasing, especially for research. Some prototypes and demonstration units have received public support but it is still difficult for small developers to secure financial support. In December 2010, Norway and Sweden signed an agreement for a joint green certificate market to be in place by 2012.

OCEAN ENERGY POLICY

The Ocean Energy Bill, which regulates renewable offshore energy production, entered into force in July 2010. According to this new legislation, licenses to build offshore wind, wave and tidal farms in certain far-shore geographical areas cannot be given without a prior governmental process where suitable areas are identified, made subject to consequence assessments and opened. 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 windpower. Meanwhile, the licensing body, the Norwegian Water Resources and Energy Directorate (NVE), has continued to prioritize small-scale demonstration projects located near shore, according to the existing Energy Bill. The licensing process is efficient and pragmatic.

ENOVA (a state-owned enterprise) continues to offer capital grants for full-scale demonstration projects of marine renewables. While up to 50% of eligible costs can be covered, ENOVA's funding is limited in absolute figures.

RESEARCH & DEVELOPMENT

Norway has no special policies or programmes dedicated to ocean energy, but ocean energy is included in more general renewable energy policies and programmes. Overall funding for renewable energy R&D made available through the Norwegian Research Council, Innovation Norway and ENOVA has increased significantly over the last years. This has also resulted in increased funding for ocean energy projects as well, from research to prototypes and demonstration.

The research cluster in Trondheim, comprising the Norwegian University of Science and Technology (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 modeling. MARINTEK's model tank is also used to test ocean energy devices.

Runde Environmental Centre (REC) is located on Runde Island, off the Norwegian west coast. REC is a research station with activities in marine biology, oceanography and ocean energy. In 2009, REC was selected as one of 3 competence centres for renewable energy in the regional municipality. In the period from 2010 to 2013/14, approximately € 750,000 will be invested in creating an exhibition and information centre devoted to ocean energy and the surrounding ecosystem.

Following the test activities of the Seabased "Maren" wave power project in 2009/2010 (Vattenfall/Tussa) several other companies are locating test activities on Runde. As a consequence, REC is establishing a test site during 2011. In addition to existing locations, a test area covering approximately 3.5 km^2, located within sight of the REC building, is under development. The area is exposed to the open sea, but also incorporates sheltered areas for testing under both severe and more benign conditions, in depths between 0 and 100 meters. The distance to shore is less than 1 nautical mile (nm) and infrastructure to bring produced power to shore is planned.

REC has developed leading in-house competence on environmental monitoring and offers ROV survey, field sampling and laboratory facilities to investigate environmental impacts of the tested devices. The test site is being developed in co-operation with the local marine industry to ensure customers find world-class services for all other necessary disciplines, making it an ideal location to perform extended product development, survivability and endurance tests, as well as technology qualification testing prior to field development.

Statkraft has an ocean energy research programme within wave and tidal energy in cooperation with NTNU, Marintek and Uppsala University in Sweden. The programme funds a professorship, seven PhD students, a post doc. and four research projects. Thematically, the programme covers numerical classification of wave technologies, improved efficiency and optimised resource usage in wave energy arrays, modelling of wave energy, tidal devices in combined current and wave exposed areas, new design models for tidal devices and vertical tidal turbines. The programme has also a substantial activity within environmental aspects of ocean energy.

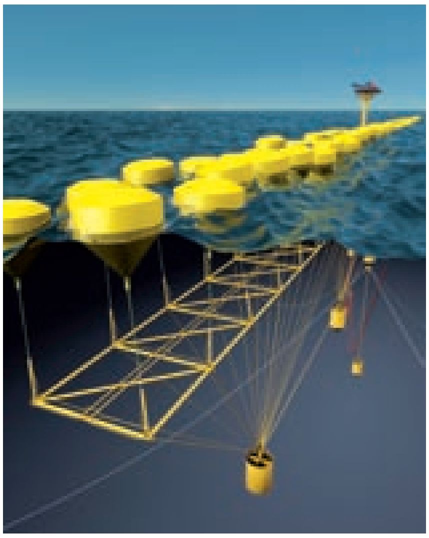
TECHNOLOGY DEMONSTRATION

Hydra Tidal Energy Technology

Since 2001, Hydra Tidal Energy Technology (www.hydratidal.com) has been developing Morild, a floating power plant that can produce electricity from coastal currents, ocean currents and tidal currents. The company has recently completed Morild II as a full-scale prototype. In September, Morild II was installed in Gimsøystraumen, a sheltered tidal race on the Lofoten Islands in Northern Norway. Later, the prototype will be tested at a more exposed location, the Moskenesstraum at the southwest tip of Lofoten. The project is financially supported by Innovation Norway and ENOVA.

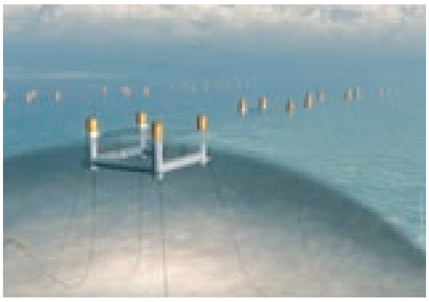
Statkraft's Osmotic Power Prototype

The osmotic power prototype generates power by exploiting the energy available when fresh water and seawater are mixed. Osmotic power is a renewable and emissions-free energy source that Statkraft has been researching into for more than 10 years and that will be capable of making a substantial global contribution to eco-friendly power production. The world's first osmotic power prototype opened in Tofte on 24 November 2009. As the first of a kind, the prototype has proven that the concept works in full scale. In 2010, the prototype was used to test improved membranes and improved water treatment systems.



Pontoon Power

The Norwegian company Pontoon Power is developing a large scale offshore wave power converter, with a maximum capacity of 15-20 MW. The concept is based on harvesting energy from the heave motion of offshore waves. The uniqueness of the concept is the load carrying structure, which makes it possible to attach a large number of energy producing pontoons to one unit without having to involve expensive seabed installations. The size of the plant allows for a dry machine room, housing one large standard turbine and one generator. The founders of Pontoon Power both have background from engineering of offshore oil and gas projects, and proven design practice for offshore marine installations will be applied through all development phases. The next step is to perform an engineering study and testing in a wave tank. The plan is to have this step finished by late summer 2011, and then start preparing for a full-scale offshore test, based on a limited number of pontoons. The Pontoon concept was selected by Nordic Cleantech Open to represent Norway as finalist in the Global Ideas Contest in San Jose, California, in 2010.

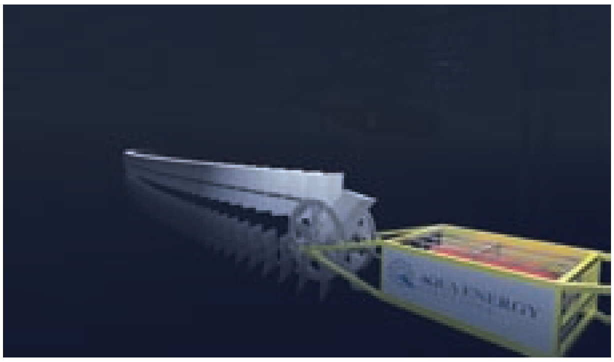


Langlee Wave Power

The Norwegian company Langlee (www.langleewavepower.com) has developed an offshore floating wave energy converter with the innovative flap/wing system designed for the horizontal movements of the wave (similar to Aquamarine Power/Oyster and AW Oy/Waveroller). The semi-submersible design for 50-150 m water depths is based on Norwegian offshore engineering and, in 2010, Aker Solutions executed analysis and structural engineering for Langlee. The second round of extensive testing at Aalborg University, Denmark, was successful. The company has entered a Co-operation Agreement with a Turkish customer for the installation of a demonstration park, which starts deployment in 2012. The planned areas for the larger installations, after a successful demo, will have an installed capacity of 28 MW and 24 MW. Langlee has signed a Letter of Intent with a New Zealand customer, in order to launch a demonstration project off Stewart Island, South New Zealand. This project will make the Stewart Island less dependent on the existing diesel power generator and will show that the costs of wave energy are competitive with other sources. Deployment is planned for 2012.

Aqua Energy Solutions

Aqua Energy Solutions (AES) has developed a new tidal stream technology, more applicable for straits and rivers. The device can also be used in open water currents by the use of pillars. The AES idea is based on a simple principle of attaching sails on wires. The tidal current pushes the sails, which pull the wires, turning a gearbox and eventually producing electrical power via a generator. The combined contribution from all the sails results in a large exposed area in the tidal stream, which allows for the production of large amounts of energy at low unit cost. The first small-scale prototype has been tested in rivers and proved that the concept works. AES is currently doing studies analysis and CFD simulations prior to building their second prototype, which is planned ready for demonstration in 2012.



Hammerfest Strøm

Hammerfest Strøm is an established player in the tidal energy scene. After 4 years of operation of its 300 kW Hammerfest Strøm's tidal device installed in 2003, an upgraded prototype was installed in the summer of 2009. This upgrade resulted in increased energy output and reliability. The company has recently received UK Carbon Trust funding for their 1 MW prototype, which will be tested at the European Marine Energy Centre (EMEC). BiFab is contracted to build the underwater structure for this prototype.

Fred Olsen

In June 2009, the company Fred Olsen deployed the wave energy buoy "BOLT", their first full-scale prototype wave energy buoy with electricity production. The point absorber unit, which has a 45 kW installed capacity, is located on the south-east coast of Norway, close to the town of Risør. The system is not grid-connected. The development of "BOLT "is a further technological advancement of their previous development and test work with the research rig "Buldra", which was deployed in 2005. As of mid December 2010, "BOLT" has endured 18 months of sea operation with electricity production. The buoy will now be moved to a harsher environment further offshore in order to test maximum operating capabilities and production performance. The successful development of BOLT has also resulted in Fred Olsen Ltd, being awarded a significant grant from the Technology Strategy Board (TSB) in the UK, and a pre-commercial, full-scale BOLT unit will be developed and deployed in the UK during 2011, followed by a second unit in 2012.

Mexico

Gerardo Hiriart L / ENAL

Research on ocean energy continues at low pace due to other priorities. Recently, important financial support for renewable energies has been announced and part of it will be for ocean energy. Mexican involvement in quantifying the potential to generate electricity from hydrothermal vents in ocean ridges is continuing.

OCEAN ENERGY POLICY

The Ministry approved a package of US$ 800,000 for 2011, to support research in the field of sustainable energies. Ocean energy projects are expected to be represented.

The IMPULSA project continues under very restricted conditions (personnel and financial support).

A successful survey has been undertaken in the National University of Mexico (UNAM) ocean research ship "Puma" in the upper part of the Gulf of California to characterize the hydrothermal vents in the Wagner Basin.

RESEARCH & DEVELOPMENT

The National University of Mexico (UNAM) has recently inaugurated a new research centre in Sisal in the Yucatan State with a laboratory for coastal studies where ocean energy is going to be an important topic.

TECHNOLOGY DEMONSTRATION

Research continues on improving the design of a floating, two vertical propellers, generator (patent has been awarded) but it is still in the model and test stage.

Spain

José Luis Villate / TECNALIA

The main step forward for the development of ocean energy in Spain in 2010 was the official announcement of ocean power targets by the Spanish Government: 100 MW of installed power by 2020 of which the first 10 MW are expected in 2016.

Another important milestone regarding ocean energy in Spain has been the organisation of the third International Conference on Ocean Energy in Bilbao. ICOE2010, organised by EVE and TECNALIA, attracted around 1,000 participants (more than 600 delegates to the conference and around 400 visitors to the exhibition), making it the world's largest ocean energy event to date.

OCEAN ENERGY POLICY

The Spanish Government announced targets for ocean energy in June 2010 by means of a first official document of the "Renewable Energy Plan 2011-2020". Targets can be summarised as follows:

- The first 10 MW of installed ocean power are expected by 2016.
- An annual growth rate of 20-25 MW between 2016 and 2020 is expected to accumulate to 100 MW by 2020.
- The average electricity production in the period 2011-2020 will be approximately 50 GWh/year with a peak in 2020 of 220 GWh/year.

The document made public by the Spanish Government includes specific measures to reach these targets. The most relevant are listed below:

- Specific legal framework for investors in ocean energy projects
- Technology development especially oriented to wave energy devices for deep water areas
- Grid infrastructure planning to facilitate the grid integration of ocean energy installations and offshore wind plants
- Research and Development on energy storage (common to other renewable energy sources)

The final version of the "Renewable Energy Plan 2011-2020" could include further measures and more detailed information, for example, about the ocean energy resource along the whole Spanish coastline. However, no changes are expected regarding ocean energy targets.

There are no additional changes in current Spanish legislation regarding ocean energy, which is defined by means of two Royal Decrees from 2007. The first establishes the administrative procedure to apply for an authorization for electricity generation installations at sea. The second sets the feed-in tariff price, so that the specific tariff is negotiated for every individual project, depending on the investment cost.

Spain is participating in several international initiatives to promote ocean energy and the European project WAVEPLAM is one of the most relevant. This project, led by EVE (the Basque Energy Agency), aims at developing tools, establishing methods and standards and creating conditions to speed up introduction of wave energy onto the European renewable energy market, tackling in advance non-technological barriers and conditioning factors that may arise when these technologies are available for large-scale development. WAVEPLAM finished in October 2010 and all the outcomes are public and available at the project web site: www.waveplam.eu.

RESEARCH & DEVELOPMENT

One of the most important current R&D project was approved at the end of 2009, funded by the Ministry of Science and Innovation within its CENIT programme. OceanLider, led by "Iberdrola Ingeniería y Construcción", includes several R&D activities with a holistic perspective, covering the following research lines:

- Identification and characterization of suitable sites and optimum resource assessment
- Technology development of wave and tidal devices, including hybrid systems with offshore wind
- Distribution, transportation, transformation and quality of electricity
- Management, maintenance and intelligent communication systems
- Technologies and systems for the operation and safety
- Preservation of resources, environmental management and climate change

The project has a budget of € 30 million (€ 15 million public funding), duration of 40 months and the participation of 20 industrial partners and 24 research centres.

R&D activities in Spain are well coordinated with other European partners by means of the participation of TECNALIA in several European projects funded by the European Commission within the Seventh Framework Programme (FP7) such as EquiMar, CORES or Wavetrain2. A new FP7 project, led by the Spanish company ACCIONA-Energy, started in January 2010, with the participation of TECNALIA as the second Spanish partner. Research in MARINA-Platform project will establish a set of equitable and transparent criteria for the evaluation of multi-purpose platforms for marine renewable energy.

TECHNOLOGY DEMONSTRATION

There are several ongoing demonstration projects in Spain:

- **Mutriku OWC plant** in the Basque Country, promoted by EVE. This consists of a multi-turbine oscillating water column system integrated in a breakwater. Some figures: € 6.4 million investment (€ 4.4 million for civil work and the rest for electromechanic work and grid connection); 16 turbines, 18.5 kW each, with an estimated overall power of about 300 kW. The turbines are expected to be installed at the beginning of 2011 and after that the plant will be connected to the grid.

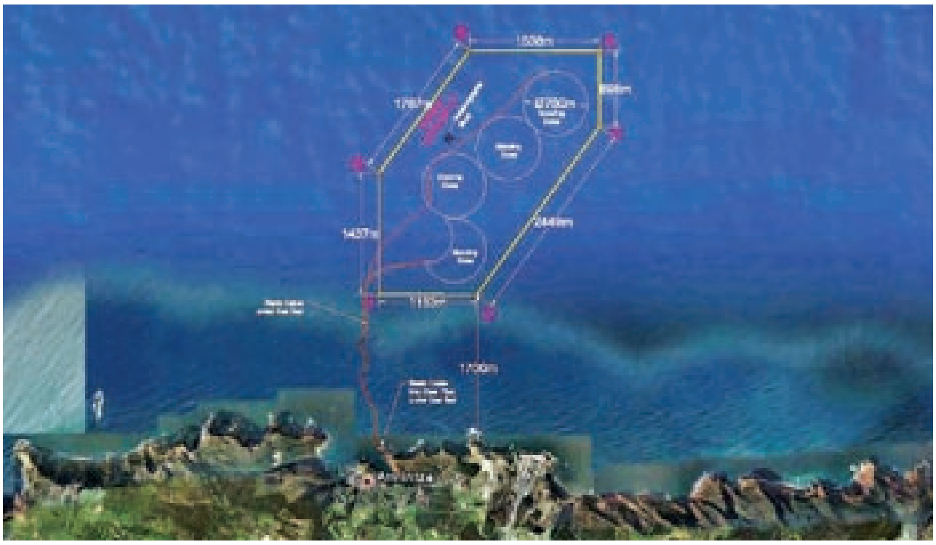
- **Wedge Project.** This consists in the installation of a grid connected wave energy converter including an innovative linear generator as power take-off (PTO) system. The project is being progressed to deploy in the Cantabrian Sea by 2012. Some critical components were successfully tested at Ciemat-Cedex facilities during 2010 (static/dynamic lab tests).

- **Abencis Seapower** developed its prototype of a "marine pump" at ¼ scale during 2010. The ultimate goal is the design and construction of a plant to convert wave energy into electricity, in a sustainable and efficient way. The prototype consists of a float-arm structure with a hydraulic system that allows the simulation of any kind of load. It will shortly be ready for testing immediately in the Mediterranean Sea. Thus, a study on sea conditions will be carried out to allow the optimization of control strategies, which will be extrapolated to a final and real scale power plant. In parallel, Abencis Seapower will also take the necessary steps to build a demonstration plant in the Atlantic Ocean in 2011.

- **WelcomE Project** of PIPO Systems, a Spanish technological company. The project involves the installation of a wave energy converter prototype based on APC-PYSIS technology (Supplemented Point Absorber) in late 2010. The installation will be around 4 nautical miles from Las Palmas harbour (Canary Islands, Spain).

WelcomE project: illustrations of several steps of development

- **bimep (Biscay Marine Energy Plaform),** promoted by EVE with an estimated budget of € 20 million. Bimep will allow full-scale prototype testing and demonstration of floating wave energy converters up to 20 MW. The oceanographic buoy installed in February 2009 has produced more than 1 year's data, which is being used to get a detailed characterisation of the bimep area. The authorisation process is progressing and, after some consultations, the promoter has decided to concentrate the reserved area down to 5.2 km^2 (35% reduction). The tender for the supply and installation of the subsea cable has been recently decided: the Basque company ELECNOR will lead an international team of experts in this enterprise.



Aerial view of the bimep area including preliminary routes of the subsea cables (red lines), exclusion navigation area (hexagon) and mooring zones (circles)

Italy

Gerardo Montanino, GSE

Increasing Italian interest in harnessing wave and tidal technology to produce clean and renewable energy can be recognized either in some government initiatives (e.g the higher incentive for such sources) or in the research activities.

Mainly universities and companies specialized in research and innovative design are involved in R&D in this field, thanks to which Italy is at forefront in research, development and demonstration at a prototypic level.

OCEAN ENERGY POLICY

Italy's major policy to support the deployment of renewable energies is based on a quota system, combined with a green certificate trading scheme that became operational in 2001 (introduced by Legislative Decree 79/99). Italian energy producers and importers, producing or importing more than 100 GWh per year, are obliged to ensure that a percentage of their annual electricity supply comes from entitled renewable energy plants (i.e., plants commissioned after 30 April 1999).

During 2009, the provision of Law 244/07 revised the Green Certificates system (GC) and introduced a feed-in tariff mechanism.

The current GC system provides, for renewable energy produced by plants commissioned after 31 December 2007, an increase in the incentive duration: they will receive tradable Green Certificates for 15 years, rather than 12 years. The total amount of GCs is differentiated by energy source, according to their technology maturity, so wave and tidal energy receives the higher support.

The renewable obligation, set for 2010 at 6.05%, increases annually by 0.75% up to 2012. In 2010, the reference price for the GC market was set, by GSE, at € 84.61/MWh (VAT included).

The above mentioned law introduced also the possibility, only for small plants (< 1 MW), to choose the feed-in tariff system, as an alternative to the GCs mechanism. The feed-in tariff grants guaranteed prices per KWh differentiated by each source, over a 15-year period.

In the case of wave and tidal energy, this supports mean 1.80 GC/MWh, equivalent to a feed-in tariff of 0.34 c€/kWh. The average market price for 2010 was about € 64/MWh.

RESEARCH & DEVELOPMENT

Universities are the key players involved in research regarding the exploitation of marine tidal and river currents to produce energy. Among these, the University of Naples "Federico II" is distinguished for its GEM project. In fact, the ADAG research group at the Department of Aerospace Engineering (DIAS), in collaboration with Parco Scientifico e Tecnologico del Molise (Scientific and Technological Park of Molise), has developed one of the most attractive projects of the last period in the field of renewable energy production, using marine sources, named GEM.

GEM project

The patented concept consists of a submerged floating body linked to the seabed by means of a tether. This hull houses electrical generators 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 is a good candidate to solve some problems involved with oscillating and reversing streams, typical of tidal currents. 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 anchorage. Releasing the anchorage cable allows the system to pop-up for easy maintenance. Special diffusers have been designed to increase the output power for very low speed currents.

After several numerical investigations, a series of experimental tests have been carried out in the towing tank of the Department of Naval Engineering at the University of Naples. The prototype tested was completely instrumented, so that dynamic behaviour and the off-nominal working conditions have been investigated.

Nowadays, the real scale prototype system of 100 kW is ready to be built and it will probably be installed by the end of 2011 nearby Venice in a very slow speed current.

TECHNOLOGY DEMONSTRATION

Actually there are two other different projects which involve the ADAG research of the Department of Aerospace Engineering of the "Federico II" University.

FRI – EL SEA Power System

Sea Power is a new groundbreaking project which consists of a vessel or pontoon, moored to seabed, to which several lines of horizontal-axis hydro turbines are attached. The same pipes, connecting the turbines through cardanic universal joints providing the necessary flexibility to the system, transfer the power captured from the water on board of the pontoon. Pipes are here connected to electrical Permanent Magnet Generators (PMG) that are kept out of the water in order to simplify and diminish their maintenance. The electric generators transform the power carried by the transmission lines into electrical energy, which can be directly fed into the grid through an undersea cable, connecting the individual floating structures to a submarine hub, which is, in turn, connected to the shore by a single submarine cable. Alternatively, the systems can be installed offshore far away from the coasts and hydrogen can be produced with the electricity generated by the turbines.

After several numerical simulations, first validation of the studies has been made by testing a prototype of the system in the water towing tank of the Naval Engineering Department of the University of Naples "Federico II". Soon after the controlled tests, a series of open water prototypes tests have been carried out in the Strait of Messina, in order to check if the system worked well in real conditions.

In July 2008, a reduced scale of Sea Power prototype (6 kW – 2.5m/s) was launched and later, in 2009, another bigger prototype (20 kW – 2.5m/s) was tested in the same waters.

The final system has been designed to be installed in the Strait of Messina and it is conceived to produce up to 500 KW with a nominal flow speed of 2.5 m/s (about 5 Kts).The real scale prototype is not yet realized but several theoretical analysis, numerical predictions, tests in towing tank and real conditions on a scaled prototype have already been carried out. Permits to deploy the final system are expected for the beginning of 2011. To this aim the new SEAPOWER public/private consortium has already been constituted by Frie-Sea Power Company and University of Naples "Federico II". The consortium will not only develop the FRI-EL Sea Power system but it will also set up and manage a real field laboratory in the Strait of Messina opened to Italian and to foreign companies that want test prototypes 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.

Kobold turbine

The Kobold turbine is being developed 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 turbine is 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 three first countries that have 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 it will be placed off Lomboc island (the island immediately to the 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 (swept area 35 m^2). The power output could be about 120-150 kW.

Ponte di Archimede International Spa has signed an agreement with the Netherlands company Bluewater to develop the Bluetec device with the scientific and technological support of ADAG Group from University of Naples "Federico II".

New Zealand

John Huckerby, AWATEA

OCEAN ENERGY POLICY

New Zealand's National-led coalition Government continues to focus on technologies/investments that can achieve early returns, e.g., promoting oil and gas exploration and potentially converting part of the Conservation Estate to land available for (hard rock) mining.

The new Government published its draft NZ Energy Strategy for consultation in July 2010, which has the following features:

- A focus on developing existing resources (gas, oil and coal), maintaining security of supply, efficient use of energy and environmental responsibility
- Maintenance of the aspiration target of 90% renewable electricity generation by 2025, as long as security of supply is maintained
- Moves away from the sustainability focus of the previous government with a more immediate focus, particularly on innovation
- Committed to a 4th round of Marine Energy Deployment Fund (MEDF) funding with a total of NZ$ 880,000 available. The 4th round closed on 29 November 2010 with any successful bids being awarded in May-June 2011.

Both the Energy Efficiency and Conservation Authority (EECA) and Ministry of Economic Development (MED) have committed to ongoing funding for international activities (OES-IA and TC114). The Ministry for the Environment continues to fund New Zealand membership of OES-IA Annex IV.

The Government has established a new Electricity Authority replacing the Electricity Commission as the national electricity industry regulator. It has also created an Environmental Protection Agency within the Ministry for the Environment. The latter has been designed to streamline decision-making processes for major infrastructure and public works projects of national significance.

New Zealand's Emissions Trading Scheme (ETS) came into effect on 1 January 2010, designed to reduce NZ's greenhouse gas emissions to 1990 levels, including the stationary energy (i.e., electricity generation sector).

The proposed National Policy Statement on Renewable Electricity Generation, which would provide guidance on decisions to regional authorities, is still under consideration by the Minister.

Perhaps most importantly, the Marine and Coastal Area Bill, which is a proposed replacement for the Foreshore and Seabed Act (FSA) 2004, is currently going through Parliament's Select Committee process. The Bill, if enacted, would remove Crown ownership of the foreshore and seabed imposed by the FSA and restore the right of customary title holders to seek ownership through the courts.

RESEARCH AND DEVELOPMENT

The Government's R&D funding agency, the Foundation for Research, Science and Technology, has been merged into the Ministry of Science and Innovation from 1 November 2010, although the amalgamation is expected to last into the New Year.

No new R&D solicitations have been announced as yet and the NZ Government continues to sponsor 3 R&D projects:

- Wave Energy Technology – New Zealand (WET-NZ) R&D Programme – Industrial Research Limited & Power Projects Limited (see next section)
- Optimizing Tidal Stream Flows in Cook Strait – National Institute of Water and Atmospheric Research (NIWA)
- Extreme Waves and Storm Surges – NIWA

TECHNOLOGY DEMONSTRATIONS

WET-NZ's second 2 kW ¼-scale prototype was deployed on 21 April but recovered due to failure of a hydraulic ram trunnion on 7 May. Final engineering drawings for WET-NZ's 20 kW ½-scale prototype have been completed and fabrication will begin before the end of 2010.

Figure 1. WET-NZ ¼-scale device at test site (left), and animation of WET-NZ ½-scale device (rigth).

Two vertical-axis tidal turbine prototypes (unrelated) are under development by local parties. Both have been trialled in open water conditions but few details have been made public.

Site Development Activities:

Crest Energy – Crest Energy first proposed a 200 MW project in the outer part of the Kaipara Harbour, north of Auckland, in 2006. Consents for the project have been granted and appealed in the Environment Court. Parties to the Environment Court case are still negotiating an Environmental Monitoring Plan, which must be approved before consent can be granted. Mediation between the parties began towards the end of 2010.

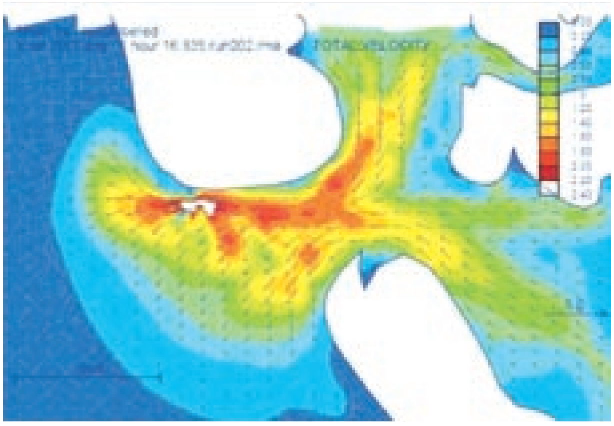


Figure 2. Tidal current velocities in the outer part of the Kaipara Harbour

Neptune Power – have consent for 1 MW tidal stream prototype. They have re-engineered their project and are currently seeking investors.

WET-NZ – on 19 March 2010 was granted first resource consent for a wave energy project off the north Taranaki coast. On 27 August 2010 WET-NZ was granted a second consent at a site off the south coast of Wellington. In late November WET-NZ was awarded a Statement of Feasibility for their device design from Det Norske Veritas.

Energy Pacifica – intends to submit resource consent applications for a 20 MW tidal turbine array in Tory Channel (top of South Island). Energy Pacifica has reportedly received some Government support.

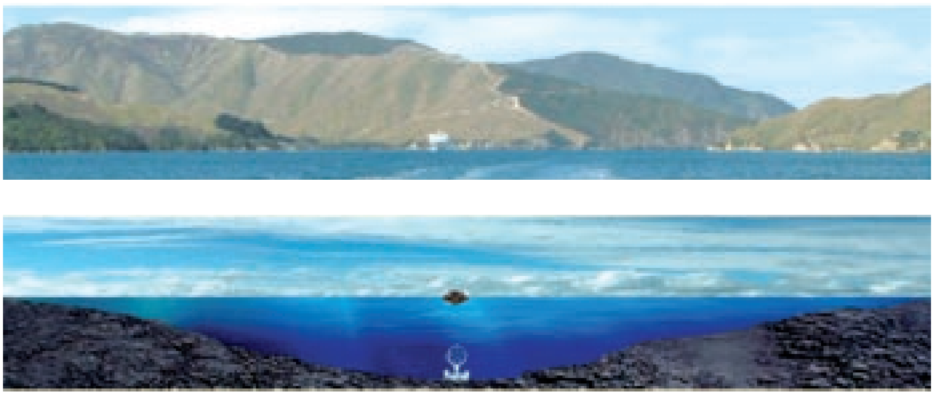


Figure 3. Cross-section of Tory Channel, the lower view shows the clearance below the Cook Strait ferry

Chatham Islands Marine Energy (CHIME) – new project announced in May 2009 to deploy a Wavegen LIMPET device on the SW coast of the main Chatham Island (800 km east of NZ). The scheme will work in conjunction with installed wind turbines to minimise the islands current use of diesel-powered generation. This is will be a landmark project for New Zealand being the first deployment of a marine energy device to provide grid connected electricity. CHIME received NZ$ 2.16 million in the 3rd Round of MEDF funding in July 2010 and was granted a resource consent on 5 August 2010.

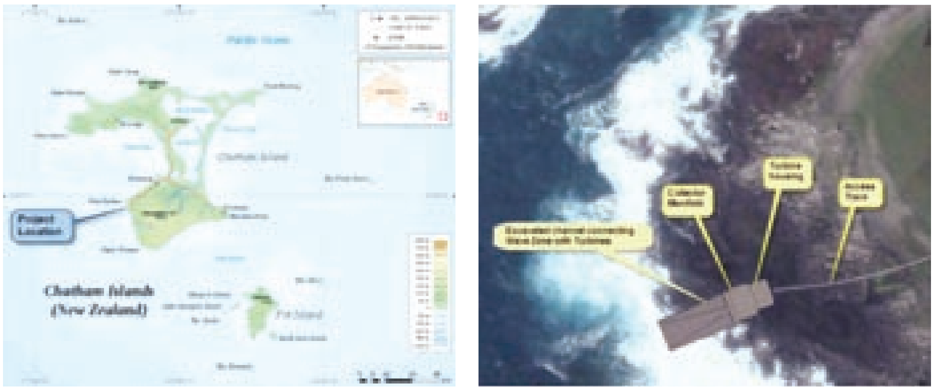


Figure 4. Map of the Chatham Islands, showing the project location (left) and the proposed layout at the Point Durham site (right).

Sweden

Susanna Widstrand and Maja Wänström, The Swedish Energy Agency

Progress has been made in several areas of ocean energy research and development. In particular, the power output of the linear generator-buoy units of Research Project for Wave Power – Lysekil Part II has been increased by a factor of two, while the material weight has been halved. Site permits for a marine current experimental facility downstream of a hydropower plant developed by the Center for Renewable Electrical Conversion II have been obtained and preparatory investigations of the site conditions of the river bed depth and water flow profile have been undertaken.

OCEAN ENERGY POLICY

In Sweden, ocean energy projects can apply all year to the Swedish Energy Agency in competition with other renewable energy projects. For all renewable energy sources producing electricity, Swedish Government support is derived from the market-based electricity certificate system, which replaces earlier public grants and subsidy systems. The principle of the electricity certificate system is to provide a market place, where sellers and purchasers of certificates can meet. The system came into force on 1 May 2003 and runs to the end of 2030. The purpose of the electricity certificate system is to increase the production of electricity from renewable energy sources and also to make the production more cost-efficient. The objective of the electricity certificate system is to increase the production of renewable electricity by 17 TWh by the year 2016 (relative to that of 2002).

RESEARCH & DEVELOPMENT

The development project "Research Facility for Wave Power – Lysekil project part II", operating on the timeline 1 June 2006 through 31 December 2010, was concluded under the co-ordination of Uppsala University. The objective of the project was to study wave power technology under real conditions and investigate the interaction between the system and the ocean environment. The project comprised the development of several linear generators with buoys and several floating buoys for environmental studies. Within the project, the generators and buoys have been developed for higher performance and efficiency, higher operational security and lower weight. The weight of the generator has been reduced by half and the efficiency of the buoy – generator system has more than doubled. The shape of the buoys has been modified accordingly with good results concerning performance and security. The development project Research facility for Wave power – Lysekil project part II is operating on the timeline 1 June 2006 through 30 June 2011. The project leader is Professor Mats Leijon of Uppsala University. The objective of the project is to study wave power technology under real conditions and investigate the interaction between the system and the ocean environment. The project comprises of the development of several linear generators with buoys and several floating buoys for environmental studies.

Within the project the generators and buoys have been developed for higher performance and efficiency, higher operational security and lower weight. The weight of the generator has been significantly reduced compared with the initial state and the efficiency of the buoy – generator system has more than doubled. The shape of the buoys has been modified accordingly with good results concerning performance and security. The wave power farm is to be connected to the local power net before the project is concluded in the summer of 2011. The research facility remains active for continued development after the project is concluded.

Linear generator-buoy units of Research Project for Wave Power – Lysekil Project

The second phase of the centre CFE II-Centre for Renewable Electrical Conversion II, operating on the timeline 1 April 2009 through 1 April 2013, is now very active. In addition to wave power, the project continuation involves basic research in the areas of marine currents and vertical-axis wind. In all technology areas of study, the centre methodology is a whole system approach which also involves basic theory and computer simulations for optimization. The project is coordinated by Uppsala University and the total project budget is € 4.85 million. At present, the centre involves 12 senior researchers and 12 Ph.D students. Several articles have already been published.

In the marine currents area, test permits have been obtained for the experimental site in Söderfors, where a vertical-axis turbine will be positioned between two hydro power plants during 2011. In order to optimize the experimental test design and position, the local river floor geometry has been determined and the mean flow rate profile during spring flood has been measured with acoustic-Doppler acquisition technique.

In the wave power area, research has focused on increasing energy absorption by modelling of the buoy-wave-generator interaction. Optical measurements of buoy motion during various wave climates have been made with the purpose of model verification but also for further study of structural dynamics of the buoy-wire units. Models for the wave power available in geographical-dependent polychromatic shallow water waves are being developed in order to optimize estimates for the wave power technique utilized. Electrical control systems for optimal utilization of available wave power through resonance effects are under investigation.

At the full-scale experimental site in Islandsberg, Sweden, four new generator units have been positioned in the sea, resulting in a total of 7 generators now in place. The switch-gear unit that manages the electricity produced is being upgraded to handle the increase in generated power.

For more information:

- Research Facility for Wave Power – Lysekil project part II
  www.el.angstrom.uu.se/forskningsprojekt/WavePower/Lysekilsprojektet_E.html
- Centre for Renewable Electrical Conversion II – marine currents
  www.el.angstrom.uu.se/forskningsprojekt/Electric%20power%20generation%20from%20marine%20currents.html
- Centre for Renewable Electrical Conversion II – wave power
  www.el.angstrom.uu.se/CFE/CFE_se.html

TECHNOLOGY DEMONSTRATION

The technology demonstration project Performance Test of Wave System, with a nominal timeline from 15 December 2007 to 31 December 2010, will be extended for one additional year due to a change of test site. The project leader is VD Billy Johansson at Seabased AB (www.seabased.se).

The demonstration project includes manufacturing of prototypes (four 20 kW and one 50 kW linear generators with buoys), launch (using the test facility in Islandsberg, Sweden, and probably also on Runde, Norway), connection, start-up and operation. Every step comprises measurements to investigate the performance of components and systems. Crucial components will be tested for wear and operational lifetime and extreme forces on buoy and anchors will be assessed in order to increase the reliability and efficiency of the converters. During the fall of 2010 two of the four linear generators at 20 kW were successfully launched in Islandsberg and a third is planned to be launched in the beginning of 2011. The two generators to be launched on Runde are in the last construction phase. This development phase is intended to adapt the system to large-scale production and the demonstration project is the last step before the technology is ready for the commercial market.

Australia

Tom Denniss, Oceanlinx

Ocean energy activity in Australia continues to increase, with additional projects having already been installed in 2010, and new projects planned for installation in 2011. Numerous Government funding programmes exist at the general renewable energy level, although nothing is specific to marine energy. However, specific reference to ocean energy in government policy documents is becoming much more common.

OCEAN ENERGY POLICY

No government programme specifically for ocean energy exists in Australia at present, although the relevant Government department – the Department of Resources, Energy, and Tourism – has expressed a desire to see an Australian ocean energy industry association established and to help in facilitating such a body.

No government funding schemes specific to ocean energy currently exists in Australia, although numerous grant schemes are in operation for the development and deployment of renewable energy. Ocean energy generally qualifies for all these. These grants are associated with the Government institutions set up to address climate change. Among these is the Australian Centre for Renewable Energy (which started this year), which is overseeing the $435 million Renewable Energy Demonstration Program (REDP).

Renewable energy supportive policies and activities include the Renewable Energy Target (RET) of 20% by 2020, and a legislation for a Carbon Pollution Reduction Scheme (CPRS), involving an Emissions Trading Scheme (ETS), which has now been shelved to 2013 (although this decision may change in coming months).

RESEARCH & DEVELOPMENT

Universities in Australia that are active in ocean energy research include the University of Tasmania's Australia Maritime College, the University of Wollongong, the University of New South Wales Water Research Laboratory (WRL), and the University of Sydney. It is likely that any others have some level of activity in ocean energy research.

The University of Wollongong is the recipient of a three-year duration Australian Research Council Grant for wave energy studies in collaboration with Oceanlinx, and the University of Tasmania will likely be applying for a similar grant in coming months.

TECHNOLOGY DEMONSTRATION

Ocean Power Technologies (OPT): as reported in the 2009 Annual Report update, the Australian Government's REDP fund awarded OPT a A$66.5 million grant for a wave energy project with a peak capacity of 19 MW in Portland in the state of Victoria. The project is being developed in conjunction with the large Australian based construction company, Leightons. The project will require matching funding of 2 for 1, indicating a total project cost of at least A$200 million.

Oceanlinx: Results from Oceanlinx's one-third scale floating wave energy model, dubbed the MK3PC, have been reported as exceeding expectations in regard to performance. The unit was deployed for three months, from February to May, 2010, and operated successfully during that time as one of the world's first grid-connected generators of electricity from ocean waves. Although the MK3PC unit did break free of its moorings in extreme sea conditions on May 14, several weeks prior to its planned decommissioning, it had provided ample performance data up till that time, including independent electrical generation data from power off-taker, Integral Energy, confirming the production of consistent grid-quality electricity supplied to their local customers in the Illawarra region. A six month third-party investigation, independently commissioned by Oceanlinx and the insurers of the MK3PC platform, has concluded that the design of the unit at Port Kembla was not at fault in regard to its loss. A number of commercial follow on projects are being considered in the northern hemisphere.

BioPower Systems is currently dry-testing its power conversion modules at a factory facility in Sydney. The two self-contained modules, each capable of producing 250 kW, are being developed for use in the company's Australian pilot projects. The first ocean deployment of a bioWAVE device is currently planned to occur near Port Fairy, Victoria. The company is also investigating projects in Spain, USA and at other sites in Australia.

Wave Rider Energy Pty Ltd is currently in the development stage for a first pilot plant in South Australia near Elliston, Eyre Peninsula. The launch of the pilot plant is scheduled for 2011.

Carnegie Corporation continues to develop its 5 MW project off Garden Island, near Perth in Western Australia. The project is partially funded by a A$12.5 million grant from the Western Australian Government, and is expected to be commissioned in 2011. Carnegie has also announced the receipt of licences for projects in other parts of Australia. Carnegie has also announced the signing of a Memorandum of Understanding for a three-stage 15 MW project on La Reunion in the Indian Ocean.

Perpetuwave have developed a 1:4 scaled concept prototype, which has been tested in bay type wave conditions in Australia. The company is currently investigating two commercial scale projects in locations outside Australia.

Other wave and tidal energy companies in Australia developing technologies include Elemental Energy Technologies, Advanced Wave Power, Cetus Energy, and Sundermann Water Power. One developer, Protean Power, has recently gone into voluntary receivership.

Republic of Korea

Keyyong Hong, Maritime and Ocean Engineering Research Institute, KORDI

Ocean energy activities and their budgets continued to grow in Korea in 2010. Both public and private funding significantly increased and total budget for ocean energy R&D amounts to €13 million in 2010. Korea targets to supply 11% of national energy demand from new and renewable energy by 2030, and the ocean energy contributes 4.7% to total new and renewable energy supply which amounts to 1,540kTOE. While a portion of demonstration projects were expanded, fundamental R&D projects diversify in device types and involved organizations. Ocean energy R&D in Korea has covered the tidal barrage power in west coast, the tidal current power in south coast and wave power in east and south coasts. In addition, the first major project on ocean thermal energy conversion was initiated by MLTM (Ministry of Land, Transport and Maritime Affairs) in 2010. The FIT (Feed-In Tariff) policy for ocean energy promotion is currently applied only to tidal barrage power and RPS (Renewable Portfolio Standard) policy will be initiated from 2012.

OCEAN ENERGY POLICY

Two ministries, MLTM (Ministry of Land, Transport and Maritime Affairs) and MKE (Ministry of Knowledge Economy), lead the national promotion for ocean energy research, development and demonstration. MLTM mainly supports demonstration projects under the "Practical Ocean Energy Technology Development Programme". MKE is mostly funding fundamental R&D projects under "New and Renewable Technology Development Programme" though it operates other promotion programmes including demonstration and commercial promotion.

Since the FIT system was initiated in 2002, until 2009 a total power of 5,163GWh was generated in power plants of a total 853MW capacity and its budget amounts to € 294 million. The first FIT applied to ocean energy is at Sihwa tidal barrage power plant, which is classified to a category of the tidal barrage power plant in capacity more than 50MW without a tide embankment. Its standard price is 62.81 Korean Won. It is announced that the RPS policy will be enforced to utility companies from 2012. The RPS policy requires to supply 2% of total electricity by renewable energy in 2012 and to increase its portion to 10% in 2022.

RESEARCH & DEVELOPMENT

- In 2010, several R&D projects were completed. A list of finished projects, principal research organizations and supporting organizations is as follows: 1) "development of floating marine current power generation system", Ocean Space, Inc., KETEP (Korea Institute of Energy Technology Evaluation and Planning) of MKE, 2) "development of wave energy utilization system using wave overtopping reef with spiral guide vanes", MOERI(Maritime and Ocean Engineering Research Institute) of KORDI, KETEP of MKE, 3) "investigation of ocean energy distribution and feasible power capacity at the south sea of Korea", KORDI (Korea Ocean Research and Development Institute), KETEP of MKE, 4) "feasibility study of tidal barrage power generation on the west coast of Korea", KORDI, MLTM.

- A list of projects newly launched in 2010 are as follows: 1) "practical application of micro power system with vertical axis hydro turbines", Ecocean Co., Ltd., KETEP of MKE, 2) MW class tidal stream system for ocean tidal power farm", Hyundai Heavy Industry Co., Ltd., KETEP of MKE, 3) "development and sea trial of wave energy converter with variable liquid column oscillator", KEPRI (Korea Electric Power Research Institute), KETEP of MKE, 4) "application of floating wave energy converter utilizing hydraulic pumps", Taekyung Industry Co., Ltd., KETEP of MKE, 5) "development and demonstration of wave energy converter based on floating pendulum principle", MOERI of KORDI, MLTM.

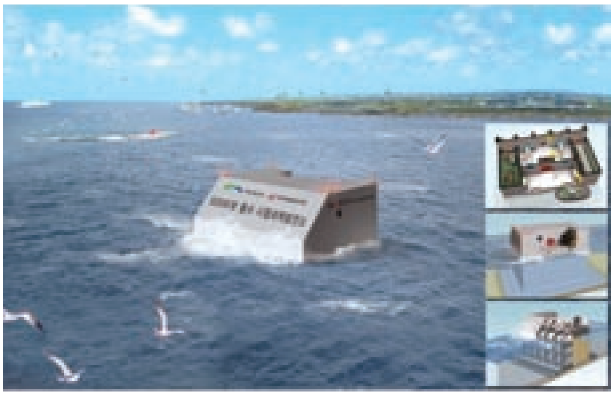
- A national programme promoting ocean energy education, research and development in universities was initiated in 2009 and it is funded by MLTM. The Korea Maritime University and Inha University are beneficiaries of the programme. Also, the Kwandong University, Wonkwang University and Pohang University of Science and Technology are partially supported to provide ocean energy courses for graduate students. In addition, the Korea Maritime University was designated as the Key R&D Center for Tidal Current Technologies by MKE.

TECHNOLOGY DEMONSTRATION

- **Sihwa TBPP** (tidal barrage power plant) of 254MW capacity has been under construction by Korea Water Resources Corporation (K-water) since 2005 and it plans to be completed in the first half of 2011. The construction budget amounts to € 241 million and it is expected to produce 552GWh annually as it operates fully. The construction process is followed by making cofferdam, excavation of foundation, developing construction site, gate and turbine housing structure installation, turbine and generator assemble, cofferdam removal in sequence. The structure and all the embedded equipment were installed and also dry test of turbine system was completed. The filling of water into turbine housing will be made by the end of 2010. A removal of cofferdam and then a wet test will be followed in the first half of 2011.

Sihwa tidal barrage power plant under construction on 1 June 2010

- Since **Uldolmok TCPP** (tidal current power plant) of 1MW capacity was completed in May of 2009, it has continued to optimize its operation in various tidal conditions and it has resulted in the significant improvement of energy conversion efficiency. The average ratio of generated electrical power to tidal current power entering into a projection area covered by turbine blades is up to 25%. It is equipped with a couple of helical turbines of 500 kW capacity and the jacket frame is applied as a basic structure. The Uldolmok TCPP includes the installation of upper house for the sheltering of facility, latticed screen for the protection against floating debris and catwalk for the connection to land. The project supported by the MLTM and a utility company of Korea East West Power Co. Ltd. (KEWP) has been carried out by the Korea Ocean Research and Development Institute since 2000. The R&D project will be completed at the end of 2010, though the KWEP will continue its operation to obtain the technical data for development of the Uldolmok tidal current site.
- **Yongsoo WPP** (wave power plant), a pilot plant of 500 kW OWC wave energy converter which has been developed by MOERI of KORDI and funded by MLTM, is going to be constructed at Yongsoo, Jeju of Korea in 2011. A couple of turbines and generators of 250 kW capacity have been manufactured in 2010. In 2011, a caisson structure of 16,000 ton will be constructed at a test site 1km off the coastline of Yongsoo and an underwater cable between the caisson structure and a power house on land will be installed for grid connection. It is expected to start the test operation in October 2011.



Conceptual drawing of Yongsoo OWC wave power plant

South Africa

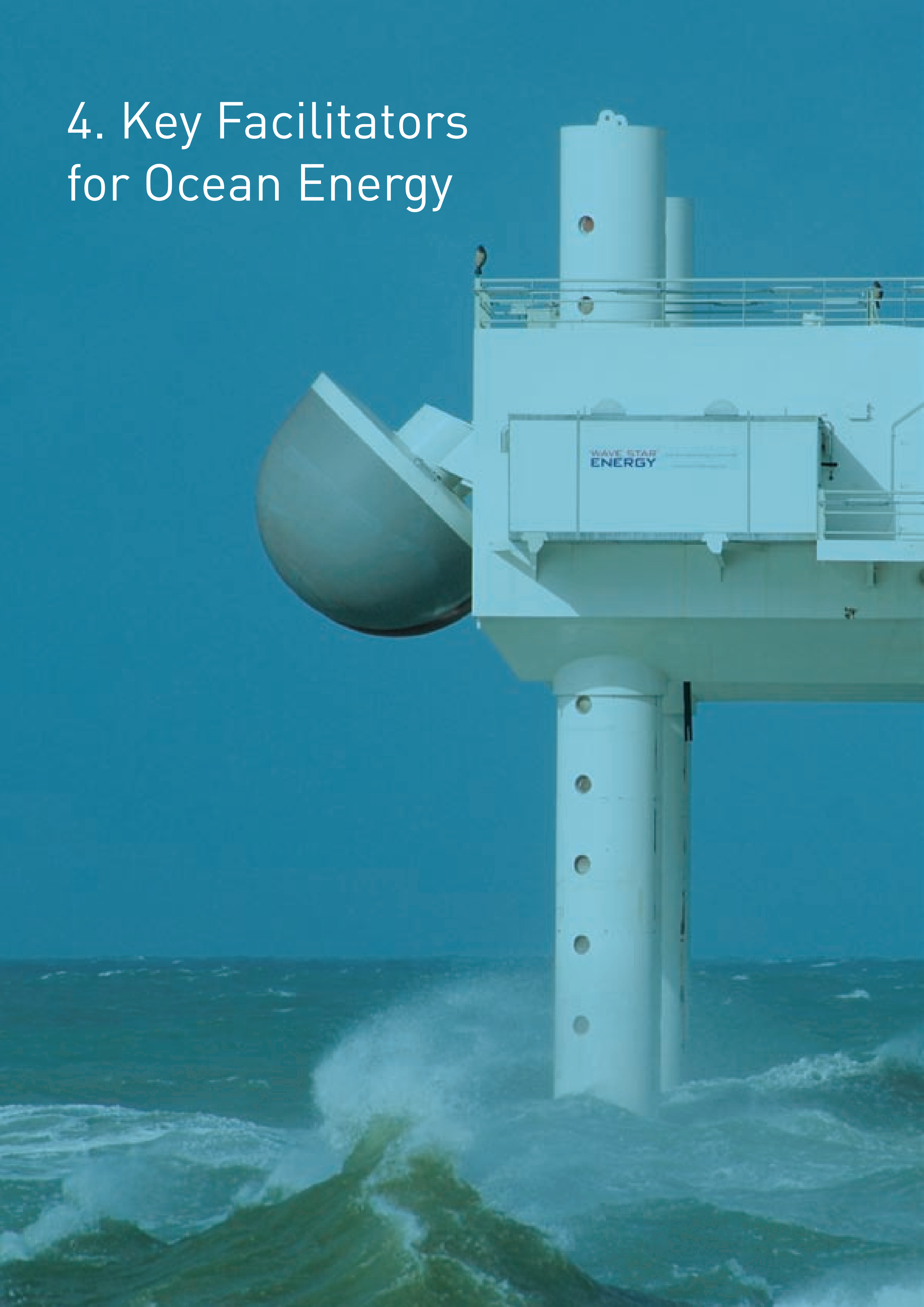
Thembakazi Mali, SANERI

There is no specific national policy in South Africa for ocean energy. Limited funding for ocean energy is available through the South African National Energy Institute (SANERI). SANERI has been developing a business plan for a Renewable Energy Centre for Research and Development (RECORD).

The Ocean Energy Research Group at the Stellenbosch University has been active in the field of ocean energy. The team has been conducting research on a wave energy device known as Stellenbosch Wave Energy Converter (SWEC), which uses an air-turbine.

No demonstration projects started in 2010.

4. Key Facilitators for Ocean Energy



Why Wave Energy – Market Driver Analysis for Investors and Policy Makers

Gordon Dalton, Hydraulic Maritime Research Centre (HMRC), University College Cork, Ireland

This paper will address the topic of 'Why wave energy' by analysis the factors for consideration from two perspectives:

- Factors for consideration by an investor in wave energy.
- Factors for consideration by a policy maker in wave energy.

1. WHY WAVE ENERGY – FOR AN INVESTOR

The first section of this paper discusses why an investor would consider wave energy as an investment option. Investors today have the option of investing their finance in an enormous range of products/companies/ventures. The principal criteria which will determine their decision to invest will be the expected return on their investment (some investments are driven by personal or philanthropic reason, but these are a minority).

With return on investment as the driving force, an investor will compare wave energy projects to a host of other possible ventures. Investors usually specialise in certain product or industry sectors, determined by their past experiences and expertise. Thus, investors in wave energy will be familiar and interested in the energy sector in general, and more than likely have an interest in renewables.

This paper investigates 'why wave energy for a investor' by assessing all the criteria and facts that an investor will need to investigate in order to make a decision on the viability for investment in either wave energy research, development, manufacture or deployment sectors.

1.1 Supply Analysis

1.1.1 Global Fossil Fuel Deposits

The level of global fossil fuel reserves will have a direct bearing on the future attractiveness and viability of renewable energy. Accurate forecasting of this trend will dictate investment in renewables.

Statistics presented in Table 1 indicate that there is ample coal reserves left for nearly 200 years. Thus an investor could be wary of investing in wave energy technologies or wave farm development in countries that have large deposits of coal, or access to cheap coal. On the other hand, oil reserves have less than 50 years left. Thus countries heavily dependent on oil imports would be countries most likely to require high renewable energy targets in the near future to offset the high price of oil which will inevitably result from future limited supply. In summary, countries that have limited fossil fuel reserves and large wave energy capacity are the optimum countries on which to focus investment.

Fossil energy source	Reserve (Resource) (Gtce)	Production Rate (Gtce)	Static Depletion time (years)
Total	1279 (6224)	13.1	98
Oil (conventional)	233 (118)	5.5	42
Natural gas (conv.)	196 (230)	3.0	65
Coal (hard and lignite)	697 (3541)	4.1	170
Uranium, Thorium	56 (293)	0.5	101

*Expected additional resources

Table 1. Fossil reserves, resources, consumption rates, depletion time, and solar delivery times [1] (Giga tonnes coal equivalent (1 Gtce) = 29 EJ = 8,140 TWh thermal = 5 Billion bbl)

1.1.2 Cost of Fossil Fuel Deposits

High and fluctuating fossil fuel prices are a major driver for the competitiveness and utilisation of renewable energy technologies [2]. Since 2000, the prices of fossil fuels, and in particular oil prices, have increased significantly by approximately three times (Figure 1). Oil prices are forecast to continue to increase in price for the foreseeable future. These price fluctuations may provide an essential driver for investments in renewable and wave energy technologies.

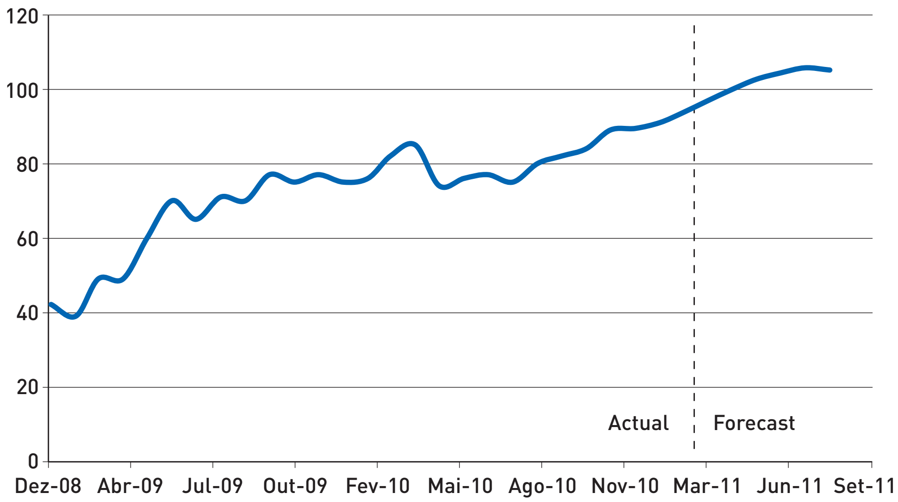


Figure 1. Crude oil past & future projection. West Texas Intermediate in US Dollars per barrel.1

1 http://www.forecasts.org/oil.htm

1.1.3 Supply Predictions for Wave Energy

An investor will need to assess the predicted maximum capacity that wave energy can produce given ideal conditions, and compare these to exiting onshore and offshore wind competition. Wave energy is predicted to supply 188GW of renewable power to Europe by 2050, and will have a similar proportion of the renewable energy mix as offshore and onshore wind (Figure 2) [3]. An estimated 150 GW of wave energy production by 2030 would contribute 11-14% of total electricity consumption In Europe[2].

In 2007 the countries of the European Union consumed 2,926 TWh of electricity [3]. Ocean energy generation has a potential to reach 3.6 GW of installed capacity by 2020 and close to 188 GW by 2050. This represents over 9 TWh/ year by 2020 and over 645 TWh/year by 2050, amounting to 0.3% and 15% of the projected EU-27 electricity demand by 2020 and 2050 respectively. The numbers presented are achievable targets for ocean energy at the European level. The vast quantity of available wave energy is therefore a sizeable energy reserve that can be tapped for investment.

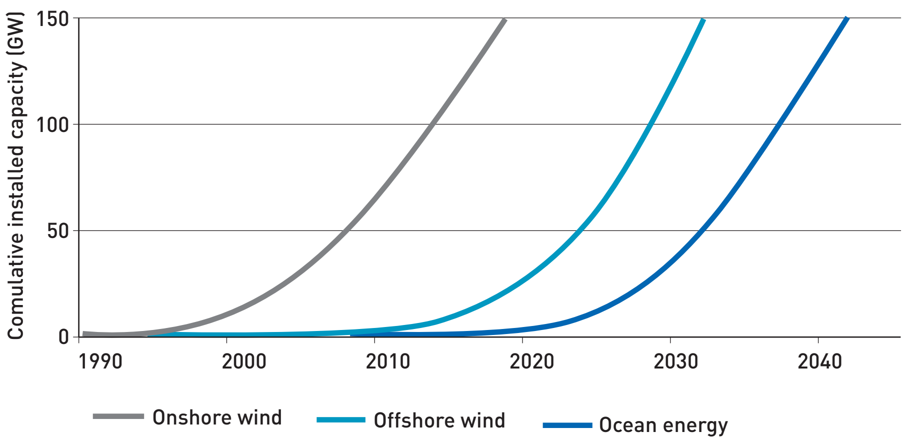


Figure 2. Estimated installed capacity of onshore, offshore wind and wave energy [3].

1.2 Demand Analysis: Fossil Fuel and Green Energy

Investors interested in the energy supply market will need to do a full assessment of future demand for the following:

- General energy consumption and electricity consumption.
- Green energy/electricity consumption.

1.2.1 General Energy and Electricity Demand

The German government's scientific advisory board on global energy consumption assumes a rise by a factor 4 to 1,600 EJ or 55 Gtce (Giga tonnes coal equivalent, 1 Gtce = 29 EJ), respectively, from the year 2000 until 2100 [4]. Forecasts from the US indicate the energy demand will double until 2030 and electricity demand will triple (Figure 3).

2 http://www.ewea.org/index.php?id=60&no_cache=1&tx_ttnews%5Btt_news%5D=1361&tx_ttnews%5BbackPid%5D=1&cHash=a082035a00

In conclusion, investors should view the strong forecasted demand growth for energy and electricity as positive indicators for future investment consideration in the energy sector.

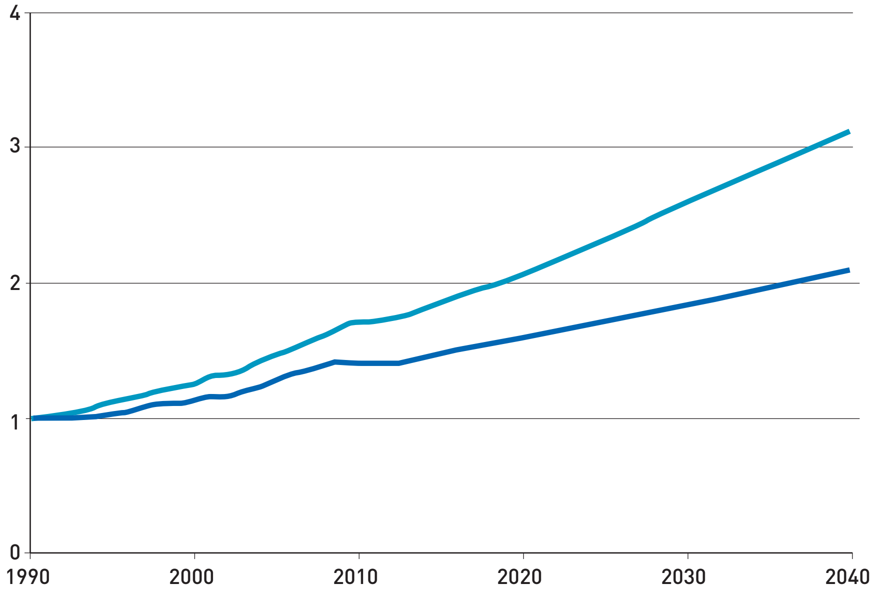


Figure 3. Growth in world electric power generation (green line) and total energy consumption (blue line), 1990-2035. Index, 1990 = 1. (Energy Information Agency, US)[3]

1.2.2 Renewable Energy Demand

As fossil fuel resources are facing depletion, it is anticipated that the deficit can be filled in part by renewable sources of energy.

Predictions by the US Energy Administration Bureau [5] indicate the renewable energy has a strong growth market increasing at the same rate as the other fuel types (Figure 4). Figure 5 splits the renewable portion of the fuel mix into its constituents. Knies [4] reports from a German study that solar will be the most prevalent renewable energy form by 2050 and ubiquitous by 2100. 'Others' described in the graph could refer to wave energy, but is not qualified. A more conservative report from EC.Europa [6] sees a modest growth of all fuel types with biomass as the greatest growth fuel. Wave energy is not described in any graphs of the types, however it is assumed that it forms some portion of the "others". The current market proportion is certainly small in comparison to other renewables, but one can assume that it will be a growing one if it follows the trend that other renewables have taken, such as offshore wind [7].

3 http://www.eia.doe.gov/oiaf/ieo/electricity.html

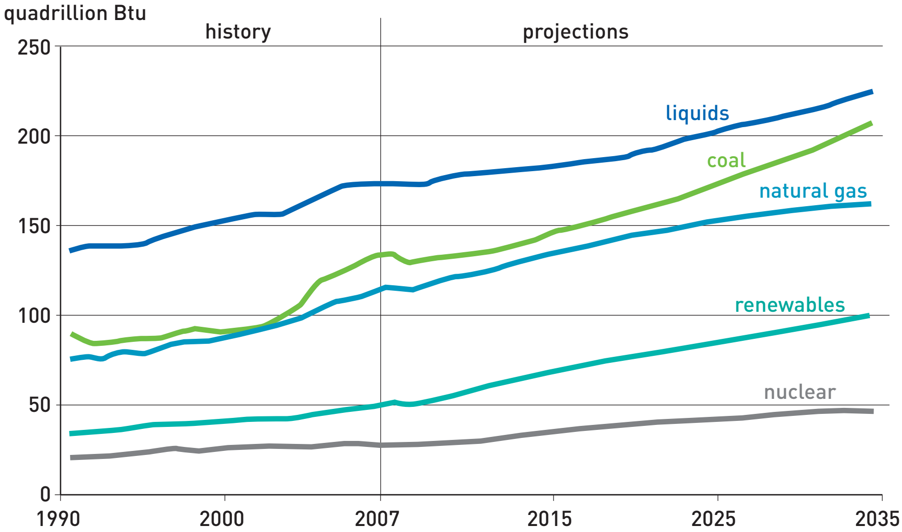


Figure 4. Energy fuel mix predicted for 2015, 2025 and 2035 (Energy Information Agency, US) [5]

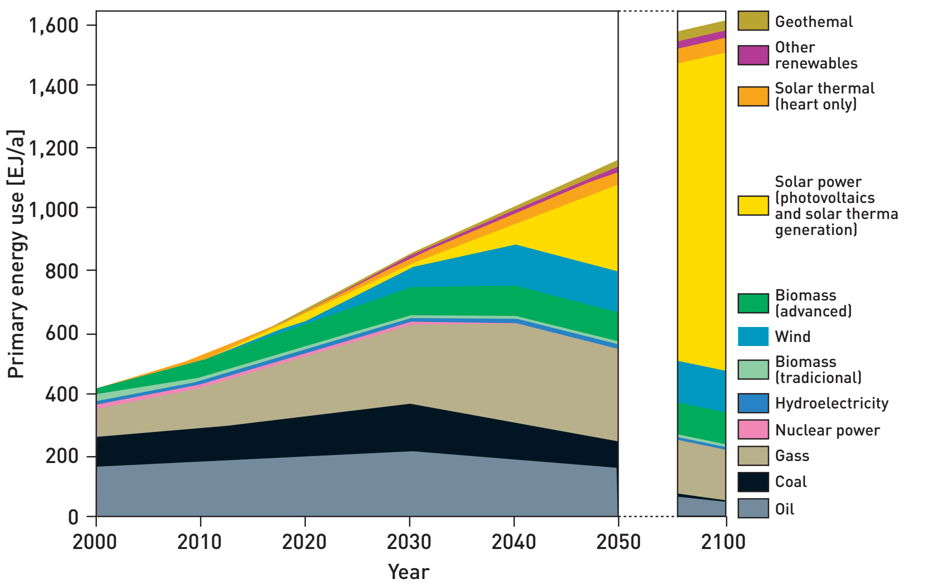


Figure 5. Development of global primary energy demand according to the scenario "exemplary path" by the scientific advisory board (WBGU) to the German government [4].

1.3 Target Penetration of Green Energy

Investment in renewable energy technologies in certain countries will be directly proportional to the strategic plan of the national government of the country. National targets have been set in most European countries for:

- Renewable energy- general targets.
- Wave energy specific targets.

1.3.1 Renewable Energy – general

National renewable energy targets for European countries are displayed in Figure 6. The countries with the highest targets by 2020 are Denmark, Estonia, Spain, France, Austria, Portugal, Finland and Sweden.

	Share of energy from renewable energy (%), 2005	Share of energy from renewable energy (%), 2020
Malta	0	10
Luxembourg	0.9	11
Belgium	2.2	13
Cyprus	2.9	13
Czech Republic	6.1	13
Hungary	4.3	13
Netherlands	2.4	14
Slovakia	6.7	14
Poland	7.2	15
United Kingdom	1.3	15
Bulgaria	9.4	16
Irland	3.1	16
Italy	5.2	17
Germany	5.8	18
Greece	6.9	18
Spain	8.7	20
France	10.3	23
Lithuania	15	23
Romania	17.8	24
Estonia	18	25
Slovenia	16	25
Denmark	17	30
Portugal	20.5	31
Austria	23.3	34
Finland	28.5	38
Latvia	32.6	40
Sweden	39.8	49

Figure 6. EU national targets for the contribution of electricity produced from renewable energy sources in percent (%) of gross final consumption, comparing 2005 to 2020[4].

1.3.2 Wave Energy Targets

The UK has the highest wave energy target for 2020, at 2GW (Figure 7). This is double that of France and 4 times that of Ireland, Portugal and Denmark. However, it must be remembered that the UK has 10 times the population of

4 http://ec.europa.eu/energy/renewables/targets_en.htm

these countries, so for per head of population perspective, Ireland, Portugal and Denmark are setting very high targets. Thus the investment made by these countries as a percentage of the total budgets in renewable energy is high, and can be taken as a positive indicator for investors as attractive locations for investment.

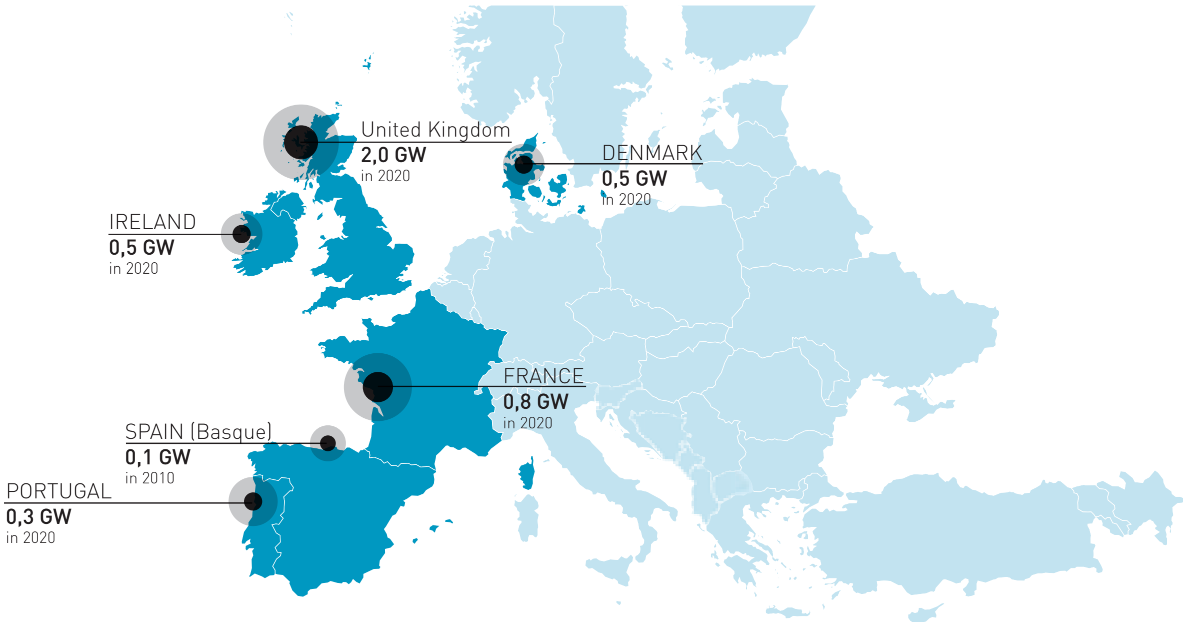


Figure 7. Current and future targets for ocean energy for European countries [3].

1.4 Capex and COE

An investor needs to ask "is the cost of renewable (and wave energy) competitive with other forms of energy"? The costs ultimately must be as attractive as fossil fuel prices to be worthy of investment consideration in the long run.

1.4.1 Capital Expenditure (Capex)

Capex is cost per kW (€/kW) or per MW (€/MW). This metric gives a direct relationship between the initial cost of the device and its rated power. It is neither location specific nor account for revenue. Statistics available for the Nuclear Association [8] show that that there is a wide range of Capex for various energy sources. Onshore wind is still more expensive than conventional fossil fuel sources such as coal and gas but cheaper than nuclear power (Figure 8). A more detailed literature review costs for offshore wind is displayed in Table 2 indicating that moving offshore incurs a higher cost than onshore wind, with Capex as high as € 4500/kW. Wave energy also is predicted to have a high Capex, ranging from a low of € 1400/MW to a high of € 8-10,000 by Dalton [9] and Cameron [10]. These very high Capex costs will require substantial support mechanisms to make wave farm ventures viable. It would also be assumed that learning curve and market demand will help reduce the Capex over time to similar levels of onshore wind. However, this cannot be assumed or expected, as per the example of offshore wind, where the price per MW doubled from year 2000 to 2010 [11], due to supply not meeting demand, as well as price increase in raw materials.

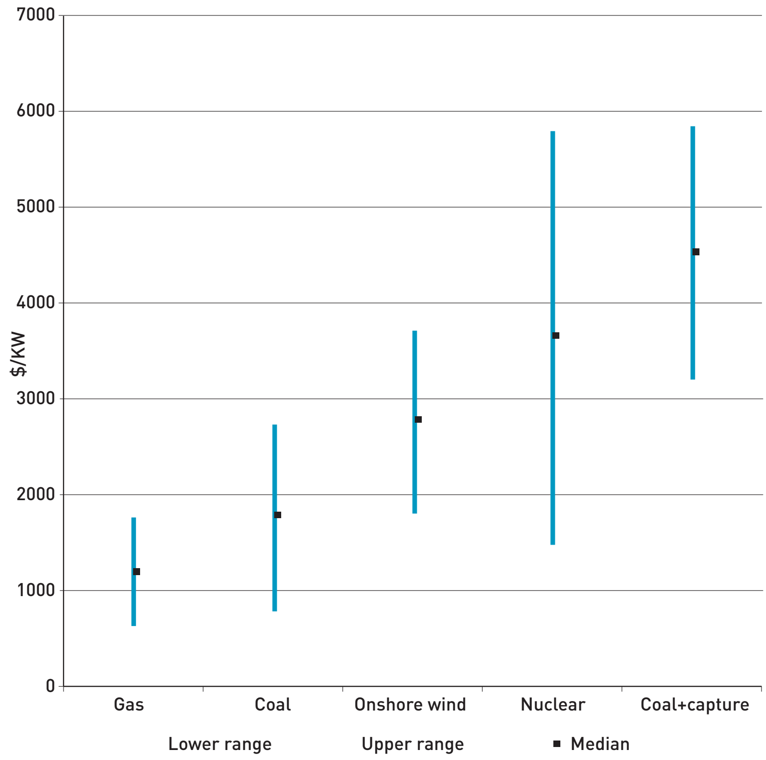


Figure 8. Cost per KW for various technologies, showing upper, lower and median value ranges. [8]

Technology	Author	Year	Reference	Turbine or farm size	€/kW
Offshore wind	Snyder and Kaiser	2009	[12]	1-2MW turbines	1500-3000
				2-5MW turbines	2000- 3000
				1 – 50MW farms	1500-3000
				50 – 200MW farms	2000-3000
	Fingersh et al	2006	[13]	3MW	1500 ($2100)
	DETI	2002	[14]	Not quoted	1400-2000
	Horns Reef	2002		160MW	1700
	Barthelmie et al.	2008	[15]	Not quoted	1650
	Luypert et al	2008	[16]	Not quoted	2500
		2010		5MW	3500-4500
Wave energy	Weiss	2007	[17]	90MW	1800 ($2600)
	Carbon trust	2006	[18]	commercial	1400-3500
	Previsic (calculated from report)	2004	[19]	1MW	5350 ($7500)
				105MW farm	1900 ($2600)
	Dunnett	2009	[20]	Not quoted	2500 ($3500)
	Aquamarine	2010	[10]	1MW	90001
	Dalton	2010	[9]	1MW	8000
				20MW	5800

Table 2. Cost per kW for various offshore wind and wave energy studies. (€1 =US$1.4, €1 =£0.82)

1.4.2 Cost of Electricity (COE)

Cost of electricity (COE) is measured in €/kWh or €/MWH. This metric is most useful for providing an economic relationship between the cost of the project and the electricity output. COE is location specific and does not factor in revenue. The metric can be confusing as some economists include revenue in the figure, which makes it difficult to compare with other published results which do not account for it.

There are two methods to calculate COE:

a) Simple COE: The total Initial cost of the project is divided by the total annual energy output of the device per MW (not recommended).
b) Levelised COE: The levelised annual average costs of the project including all annual OPEX costs are included in the estimate. This figure provides the most accurate metric for developers.

COE for wave energy is the highest amongst other renewable energy compared, as displayed in Figure 9, similar to trends discussed for Capex. However, caution must be exercised in using COE for the following reasons:

- COE for the same technology can vary from location to location.
- COE will vary from report to report for each device. An example is displayed in Table 3 where COE obtained from different reports are quoted for the Pelamis. The COE quotes vary due to two main reasons:
  - Different locations for the device analysis provide different energy outputs.
  - Some reports include revenue support in the COE calculation, thus lowering the reported COE.

In conclusion, COE must be used with care when comparing technologies. Capex/MW can be more reliable. In general, wave energy will involve high costs, which need to be supported by mechanisms, such as grants or feed-in tariffs. These latter requirements will need to be carefully investigated in conjunction with Capex/COE analysis to gain the full picture of wave energy investment viability.

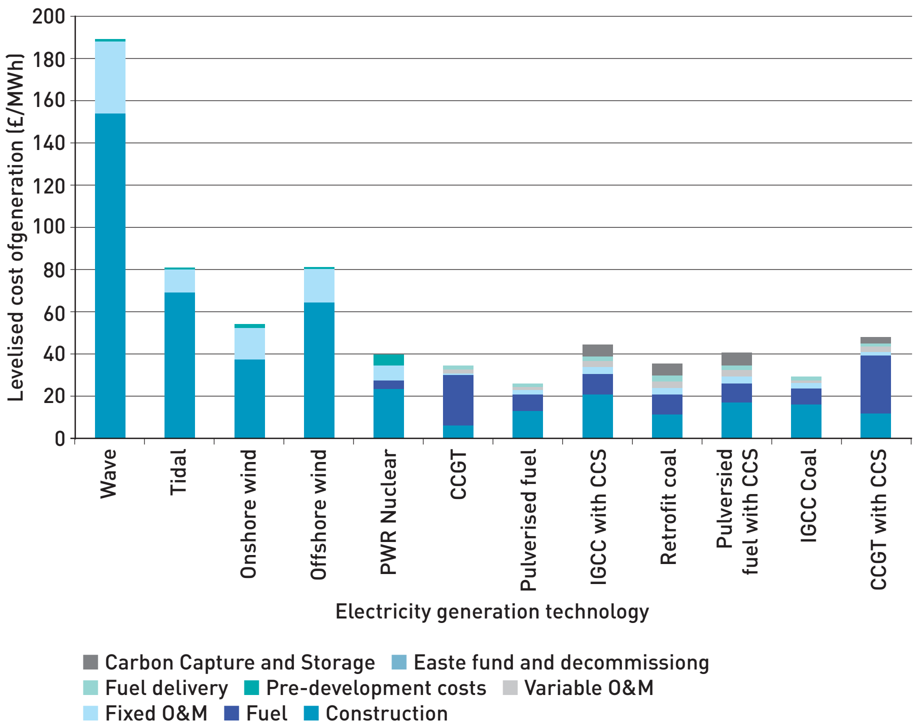


Figure 9. Cost of generating electricity (£pence per MWh). [21]

Study	Reference	Location	Year	Number of Pelamis	COE €/kWh	Subsidy
EPRI (Previsic)	[19]	California	2005	213	0.08	0.06
ESBI	[22]	Ireland	2005	209	0.105	–
St Germain	[23]	Canada	2005	15	0.10-0.15	–
EPRI (Bedard)	[24]	California	2006	44	0.05-0.12	–
Carbon Trust	[18]	UK	2006	13,000 13	0.08- 0.30	–
Allan et al.	[25]	Scotland	2008	4000	0.10	0.05
Dunnet et al.	[20]	Canada	2008	15-27	0.18- 0.30	–
Pelamis	[26]	UK	2008	1	0.08-0.16	–

Table 3. Wave energy device studies reporting COE using the Pelamis power matrix.

1.5 Support Mechanisms

An essential ingredient for consideration by an investor intending to invest in renewable or wave energy technologies is the global support mechanisms promised by the government of the country under consideration. The currently available supports mechanisms (2010) for European countries are presented in Table 4.

Feed-in tariffs (FIT) schemes are the most prevalent support mechanisms for wave energy in Europe. The second most important mechanism is grant schemes provided. At present, the UK has the most comprehensive suite of grant support schemes.

The largest support fund promised will come from the EU, called NER300[5]. The NER300 is a common pot of 300 million EU ETS allowances, which could be worth as much as € 4.5 billion if each allowance is sold for € 15. Up to 50% of *"relevant costs"* are funded under the scheme. Each member state will have allocated at least one and a maximum of three projects[6]. A total of three ocean energy projects will be funded including wave tidal and ocean thermal. Wave energy devices of up to 5MW nominal power are eligible to apply[7].

In conclusion, there are many support mechanisms available throughout Europe, either via FIT or grants. Investors will need to balance costs versus supports, as well as the local wave energy resource, to come to a final decision on whether to invest.

	Feed-in tariff (FIT)	**Renewable Portfolio Scheme (RPS)**	**Grants+ subsidy**	**Investment / tax credits**	**Production tax credits**
Austria	•		•	•	
Belgium		•	•	•	
Czeck	•		•	•	
Demark	•			•	
Estonia	•				
Finland			•		
France	•		•		•
Germany	•		•	•	
Greece	•		•	•	
Hungary	•			•	
Ireland	•		•	•	
Italy		•	•	•	
Latvia	•				
Lithuania	•		•	•	
Luxembourg	•		•	•	
Netherlands	•		•	•	•
Norway			•	•	
Poland		•	•		
Portugal	•		•	•	
Slovak	•			•	
Slovenia	•				
Spain	•		•	•	•
Sweden	•		•	•	
Switzerland	•			•	
UK			•	•	

Table 4. Global support mechanisms for renewable energy in general[8]

5 http://www.ner300.com/
6 http://ec.europa.eu/clima/funding/ner300/docs/faq_en.pdf
7 http://ec.europa.eu/clima/funding/ner300/00031/index_en.htm
8 http://nextbigfuture.com/2008/02/feed-in-tariffs-support-for-renewable.html

2. WHY WAVE ENERGIES – FOR POLICY MAKERS IN EUROPE

Government renewable energy policies are the principal driver of the growth in renewable energy use. Renewable energy policies exist in 73 countries around the world and public policies to promote renewable energy have become more common in recent years. The criteria for policy making decisions are slightly different than those for investors, when considering the options of investing in wave energy.

Policy makers will be looking at the national perspective, taking into account a larger suite of factors, not all having direct financial returns in the short term, if ever.

The following is a directory of factors that will need to be considered from a policy making perspective.

2.1 Climate Change and CO_2 Mitigation

The Organisation for Economic Co-operation and Development (OECD) states that technological innovation will play an important role in bringing down the costs of climate change mitigation over time [27]. It argues that a concerted research and development effort can be expected to yield important benefits, but not by itself. The International Energy Agency estimates that nearly 50% of global electricity supplies will need to come from renewable energy sources in order to halve carbon dioxide emissions by 2050 and minimize significant, irreversible climate change impacts [28]. With the adoption of the new "Energy from renewable sources" directive by the European Parliament and the European Council [29], the EU has committed to reducing its greenhouse gas emissions by 20% by 2020. It has been estimated that 300 kg of CO2 could be avoided for each MWh generated by ocean energy [3]. Therefore, for 20 GW (49 TWh/year) of installed ocean energy, the CO2 emissions avoided could be 14.5 Mt/year. These figures do not account for the baseload fossil fuel-produced power necessary to firm up ocean energy intermittency. The International Energy Agency (IEA) concludes, however, in the Energy Technology Perspectives Report [30] that 'it is unlikely that wave energy technology will play an important role in climate change mitigation 2030'. It points to the need to develop appropriate wave energy policies and effective measures essential to accelerate the development and deployment of wave energy technology and to address the barriers identified. If successful, wave energy could play a significant part in the effort to achieve global CO_2 mitigation.

2.2 Security of Supply

The interdependence of EU Member States for energy, as for many other areas, is increasing – a power or gas pipe failure in one country has immediate effects in other countries [3]. A radical change is required in the way energy is produced, distributed and consumed. This means transforming Europe into a highly efficient, sustainable energy economy. Europe's dependence on imported energy has risen from 20% at the signing of the Treaty of Rome in 1957 to its present level of 50%, and the European Commission forecasts that imports will reach 70% by 2030 [3]. A second EU report forecasts import dependence reaching 67% in 2030, with import dependence from oil continuing to be the highest, reaching 95% in 2030 [31].

Some major European economies are already ahead of the general trend of dependency. The TG Trend report quotes that in 2007, Germany needed to import almost two thirds of its energy, while Spain and Italy's dependency rates rose to 81.4% and 86.8% respectively [32]. With regards gas supplies, most European countries are even more vulnerable. Spain, Portugal, Sweden and the UK in 2007 relied 100% on imported gas (Table 5) [32].

	% dependant
Spain	101.3
Portugal	100.0
Sweden	100.0
UK	100.0
Italy	91.2
Germany	83.6
France	80.0
Netherlands	61.6
Denmark	-101.3

Table 5. Dependence on imported gas for selected EU countries 2007 [32]

From a European perspective, the majority of supply sources are at present from areas in the world with least government stability, as is evidenced in Figure 10. The Russia-Ukraine gas dispute in January 2009 highlighted the impact that events far away can have on the transit of gas to the EU [33].

In conclusion, the use of renewable energy technologies increases the security of energy supply because they generally utilise indigenous resources [2]. Europe's increased dependence on a limited number of energy sources, as well as supply and transport routes, should stimulate investor confidence in the need for investment in alternate energy technologies.

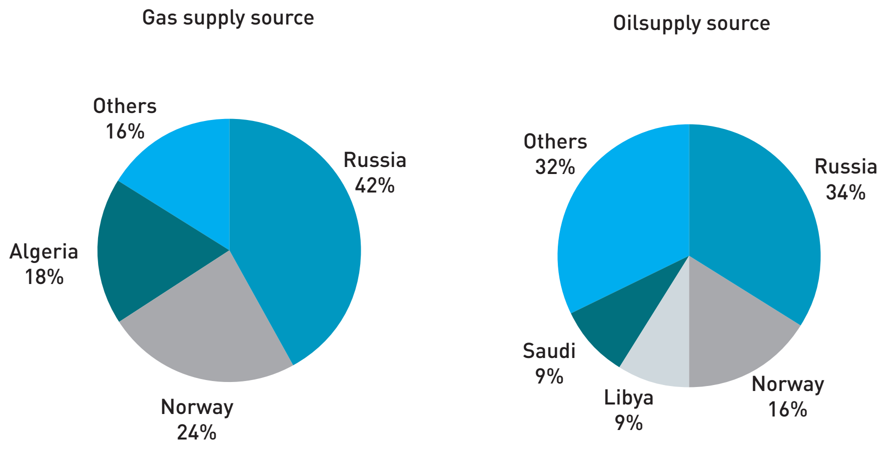


Figure 10. EU's gas and oil imports 2006 [32]

2.3 A Diversified Energy Mix

A diversified energy mix, both geographically and technologically, can resolve the issue of variability. Ocean energy can bring added value to the European Union's energy mix. Indeed, it has been established that wind and ocean energy are complementary. Studies performed on wind energy show that diversification at a national (supranational) level improves intermittency [34]. A recent Renewable UK study concludes that diversifying the renewable energy mix by including a greater proportion of marine energy would reduce requirements for reserve capacity and lead to annual savings in relation to the annual wholesale cost of electricity [35]. An Irish study concludes that the integration of wind and waves in combined farms, allows the achievement of a more reliable, less variable and more predictable electrical power production. This is particularly clear in the case of a relatively small and quite isolated electrical system such as the Irish one [36]. A British study also concluded that reducing the variability of the renewable electricity supply with a wide mix of renewables reduces the additional balancing costs required [37]. Finally, a US study also states that co-located offshore wind and wave energy farms generate less variable power output than a wind or wave farm operating alone [38]. The reduction in variability resulted from the low temporal correlation of the resources and occurs on all time scales.

In conclusion, wave energy may become a crucial ingredient in Europe's energy portfolio – improving the quality of grid supply and reducing intermittency.

2.4 Job Creation

Ocean energy is well positioned to contribute to regional development in Europe, especially in remote and coastal areas. The manufacturing, transportation, installation, operation and maintenance of ocean energy facilities will generate revenue and employment. Studies suggest that ocean energy has a significant potential for positive economic impact and job creation. Parallels can also be drawn with the growth of the wind industry. Clean technology now account for € 7.1 billion annually in Denmark, while in Germany, wind technology exports alone are worth over € 5.1 billion. Based on the projections for installed capacity, by 2020, the ocean energy sector could generate over 26,000 direct and 13,000 indirect jobs [3]. By 2050 these numbers would increase to 314,000 and 157,000 jobs respectively.

In order to meet the Irish aspirational 500MW target, the Irish wave energy industry could produce 1,400 additional full time employment jobs and a net present value (NPV) of € 0.25 billion, rising to 17,000-52,000 FTE jobs and an NPV of between € 4-10 billion by 2030 [39].

Scotland has published several roadmaps for the development of marine energy [40]. The latest roadmap developed by the FREDS Marine Energy Group [41] estimates an overall expenditure of £2.4 billion to achieve 1,000MW installed in Scotland by 2020, generating 5,000 direct jobs.

In conclusion, the wave energy industry has tremendous potential in indigenous job creation.

3. CONCLUSION

'Why invest' in wave energy is a key question that must be answered before investors and policy makers make important decisions with regards investing both funds and time in the wave energy sector. This paper reviewed the key factors and data that need to be gathered and considered to help make a full analysis and decision.

Analysis of global supply of conventional fossil fuels, such as oil and gas, reveals that deposits are dwindling, and their prices are increasing. It is predicted that renewable energy sources, including wave, will fill the resultant vacuum. However, there are locations in the world which still have ample fossil fuel reserves and may be locations of less optimistic prospects for renewable energy interest and investment.

Demand side analysis shows positive indicators, both for global energy demand as well as global renewable energy demand. Forecast demands for wave energy, which are specified by targets, are also healthy.

The negatives that must be considered at present are very high Capex costs as well as the unit cost of electricity for existing wave energy devices. Capex has reduced for most renewables with time, due to learning curves, but experience from the offshore wind industry in recent years has shown that elevated demand and supply bottlenecks can increase Capex costs with time.

Although costs can be a considerable barrier, much effort has been made by national governments to provide support mechanisms for the young wave energy industry. Support mechanisms consist of feed-in tariffs, grants and national targets. The drivers for policy makers in government to provide these support mechanisms are many and encouraging for the wave energy investor. Climate change and CO2 mitigation concerns must be addressed, as well as remedies for security of supply and reducing dependence on volatile supply sources. Renewable energy, especially wave energy, provides the obvious answer to these problems. Further benefits of adopting a diversified mix of renewables range from improving power output quality by reducing intermittency and variability to economic benefits due to green and indigenous jobs.

In conclusion, the investor can be encouraged that the majority of market drivers and indicators are positive toward wave energy at the present time, when macro-economic and socio-economic factors are considered. The wind and solar renewable energy industries are providing confident indicators of promising futures for wave energy. However, cost considerations are the most pressing concern for wave energy, requiring concerted government support and future innovation to remedy these issues.

4. ACKNOWLEDGEMENTS

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International Network on Offshore Renewable Energy (INORE): Realising the potential of young researchers and offshore renewable energy

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INTRODUCTION

The International Network on Offshore Renewable Energy (INORE) is a fully autonomous organisation comprising over 500 members, 249 of which are full INOREans (Ph.D. students and early-stage industrial researchers from over 49 countries). This article outlines the need for an international network, a brief history of INORE, an overview of current activities and some future plans.

THE NEED FOR AN INTERNATIONAL NETWORK

The focus here is on offshore renewable energy, which is taken to mean offshore wind, tidal, and wave energy. When offshore renewable energy reaches its potential in the coming decades it will become a global industry. This will constitute an array of highly developed technologies and sub-industries, most of which already exist in a nascent form. As the industry grows, one of the many benefits will be the large number of jobs that will be created. Many of these jobs will be filled by experienced professionals from relevant industries, such as onshore wind, offshore oil and gas, etc. However, there will also be an outstanding need for a continuing supply of scientists, engineers, and other professionals who have advanced training specifically in offshore renewable energy.

As companies grow from small teams with a prototype device into larger manufacturing companies and service providers, huge amounts of research and development will be necessary. As these companies grow at a rate of 10s or even 100s of personnel per year, recruitment of quality staff could be a crucial bottleneck. Who are these people and where will they come from?

Many of them will be early stage researchers graduating with a PhD from one of hundreds of academic institutions around the world. The industry needs to engage with those people as early as possible; equally these people are hungry to engage with industry. The nature of academic institutions is that they are independent and no single thread ties them together. This means there is a need for a network to connect early stage researchers to each other, and to industry.

The purpose of the International Network on Offshore Renewable Energy (INORE) is to meet this need. The network is run by and for early stage researchers, and currently has over 500 individual members. Our focus is on knowledge sharing and collaboration.

BACKGROUND OF INORE

The idea of creating a network for young researchers who worked with offshore renewable energy evolved from the project "PhD Pool on Offshore Renewable Energy" which consisted of one Post Doc and three PhD students associated to the Norwegian Centre for Renewable Energy (NTNU) and financed by the Research Council of Norway. The intention of the PhD Pool was to let researchers from different fields work together in order to create solutions that are difficult to achieve without an element of interdisciplinary thinking. The PhD pool soon realised the need for a bigger community to enable the discussions needed to obtain this goal. Inspired by the blooming industry and lack of real academic co-operation across national borders, the work to establish an interdisciplinary and international network was started.

One of the key ideas was to establish a truly international network. To ensure the international spirit, an interim committee meeting with participants from four different countries was held near Trondheim in April 2007. The meeting was attended by the three initiators from Norway and three new committee members who were selected after applications. New committee members from three different countries, with different background and knowledge, were invited.

The network has since evolved and matured. The steering committee consists of elected volunteers, who serve no longer than 2 years, and the committee is partially renewed by election every year; membership is administered via the website (www.inore.org) and is growing year after year. There are currently 2 membership categories: web-member, open to anyone with an interest, and INOREan, open to early-stage/PhD researchers. INORE members represent 179 different bodies from industry, government agencies and universities.

INORE is an independent, non-profit organisation. Funding for the network's activities comes from sponsors, who have shown great support for the concept and therefore great commitment to the wider industry. Statkraft has been a main sponsor of INORE since 2007. Support in the past has also come from the Norwegian Centre for Renewable Energy (NTNU – SINTEF – IFE), Statoil (now StatoilHydro), the University of Edinburgh, Ghent University, and UKERC (UK Energy Research Centre). Specific sponsorship of the symposium in 2010 was provided by Vattenfall, MARIN, PML, PRIMaRE and RPS. Collaboration and in-kind support is also crucial to INORE's operation, and the industry as a whole has been very supportive, including collaboration with Wavetrain2, and organisational support from Renewable UK and OES-IA.

THE INORE ANNUAL SYMPOSIUM

The most important INORE activity is the annual symposium. The annual symposium is a unique, five-day residential programme that brings together early-stage researchers for an intensive experience that provides an amazing catalyst for their research.

In April 2010, INORE hosted its fourth annual symposium, which included:

- Collaborative sessions set by industry experts; Garrad Hassan, Statkraft, Renewable UK, MARIN and RegenSW
- Presentations and posters from all 56 researchers attending
- Keynote talks from Vattenfall, MARIN, NREL and more
- Site visit to PRIMaRE at the University of Exeter in Cornwall, a key research institute for WaveHub
- Panel discussion with an array of experts.

Fig. 1. attendees at the fourth annual INORE symposium, bringing together young researchers and industry for a week of knowledge sharing and collaboration.

The symposium took place in the bucolic surroundings of Dartmouth in Devon, UK. 56 early-stage researchers from around the globe – mostly Ph.D. students – attended the symposium, representing 31 institutions. This unique event, which was free of charge, brought together researchers to help achieve INORE's goal of stimulating knowledge sharing and collaboration in the offshore renewable energy research community.

The symposium was fully funded by INORE – including travel costs – ensuring equal access for all researchers from around the world.

The feedback from the INORE symposium was overwhelmingly positive. The most common benefits cited by attendees were:

- The opportunity to meet collaborators
- Diversity of attendees and their subject areas, and how this opens their minds to the wider activities within the sector
- Contact with industry, to understand their needs and their perspective

The impact of this symposium on the 56 participants was profound. All the researchers returned to their institutions with new links to research in their field, and a strong understanding of the perspective of the major industrial players, such as utilities, device developers, and consultants. This has created a new generation of researchers who, as well as proving themselves as quality researchers through the traditional academic channels of peer review journals, PhD vivas, and conferences, are also in tune with the needs of industry. This is a crucial bridge to build if the offshore renewable energy sector is to grow into the industry that it could be.

The symposium also has an impact on the industrial partners. The collaborative sessions consist of real problems set by partners, and in 2010 included RenewableUK, Statkraft, Marine Research Institute Netherlands (MARIN) and consultants GL – Garrad Hassan. The participants work in teams to provide a solution within a few days, for example a technology review or a costing analysis, and these were well received by the industrial partners. A more detailed account is published in McCombes et al. (2010).

OTHER ACTIVITIES

Collaborative research is a central part of INORE's vision and this is promoted through its International Collaboration Incentive Scheme (ICIS), which provides financial assistance to researchers at different institutions who would like to collaborate. Five awards were granted in 2010, leading to 3 collaborative technical publications so far, with more publications expected. The ICIS grants continue into 2011 with 5 grants awarded, and we look forward to seeing the outcome of these collaborative research ventures.

With members from over 50 countries, INORE is a truly international operation. This year, INORE has began its first activities in the Americas: an Americas representative was elected to the committee in April. This led to a very successful networking event for young researchers, which was held in Seattle in September – alongside the MTS/IEEE Oceans conference. This event consisted of brief research presentations and general networking and marks the beginning of further activities in that region.

Sharing the outputs of INORE activities is also important. At the 3rd International Conference on Offshore Energy (ICOE) in Bilbao, Spain, in October 2010, INORE members presented the outcome of the six collaborative sessions held at its symposium earlier in the year. INORE also held a networking event in Bilbao on the eve of the conference. Hosting a stand during the conference gave INORE excellent exposure to new members and new sponsors.

An exciting new development is our online WIKI, which is available on our website. The WIKI currently hosts posters and presentations from our symposium, plus some further work published by INOREans.

Currently, there is no central online resource for research in offshore renewable energy; publications are scattered across thousands of proceedings and journals. In the future, the INORE WIKI has the potential to be a one-stop shop for summaries of technical research in the field of offshore renewable energy, with references to publications and, where possible, direct access to those publications. This kind of extension to the WIKI is dependent upon further collaboration and funding.

FUTURE PLANS

After symposia in Trondheim, Edinburgh, Ghent and Dartmouth, the fifth annual symposium is moving south to Portugal (Alcoutim) from 8-13 May 2011. It will consist of the traditional intensive five-day meeting filled with presentations, collaboration, and discussion, for about 60 attendees, as well as local and international companies. The symposium is in the planning stages, so new members, sponsors and speakers are still welcome to become involved. This will be a unique opportunity for exposure to a select and normally diffuse community of offshore renewable energy researchers.

In 2011, we will be hosting a joint event with MARIN in Rotterdam. This new format of event will follow the OMAE conference in June 2011 and will consist of teams building a floating offshore wind turbine platform and testing the device in the wave tanks at MARIN.

Later in the year, INORE will be present at the European Wave and Tidal Energy Conference (EWTEC), in Southampton in 2011, where we hope that our ICIS travel grants will have facilitated several publications. We will also be hosting events in the Americas in 2011.

In the long term INORE's strategic goal is firstly to maintain its membership and reputation for being an excellent networking facility for researchers and industrial bodies relating to research. Secondly, we will be expanding our activities in the offshore wind sector. Thirdly, we will be adding a focus on developing countries, both on the research that takes place in developing countries, and also global research that is applied to developing countries, where the potential to have a positive impact is so great.

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ICOE 2010 – Moving Ocean Energy to the Industrial Scale

John Huckerby, AWATEA, New Zealand
António Sarmento, Wave Energy Centre, Portugal
Jochen Bard, Fraunhofer Institute, Germany
Chris Campbell, Ocean Renewable Energy group, Canada
Henry Jeffrey, UKERC, Edinburgh University, UK
Eoin Sweeney, Sustainable Energy Authority of Ireland, Ireland
Jose Luis Villate, Tecnalia, Spain

Bilbao, Spain hosted the third International Conference and Exhibition on Ocean Energy (ICOE 2010) organised by EVE (the Basque Energy Board) and Tecnalia, with the partnership of OES-IA, the European Ocean Energy Association and the local energy industrial association. ICOE 2010 took place in October at the Bilbao Exhibition Centre and combined 3 days of conferences with an exhibition plus other parallel events. The event, with the support of Iberdrola as the main sponsor, attracted the top companies in the world from the ocean energy sector with more than 600 delegates and around 400 visitors to the exhibition and parallel events. These figures **made ICOE2010 the world's largest ocean energy event to date.**

The conference was officially opened on October 6th by representatives from the Basque Government, Tecnalia and Iberdrola with a clear message supporting the development of ocean energy as an important future renewable energy source.

After the formal opening session, the Vision panel was the first specific ocean energy session of the 2010 ICOE conference. The session encompassed full international representation for the ocean energy sector with speakers from the International Energy Agency, the European Ocean Energy Association, OREC (the main United States trade group) and with regional representation from the Basque country. This session provided a unique opportunity for each of these geographical regions to describe and debate their roadmaps, visions and forward strategies for ocean energy in a common forum. This discussion displayed not only how forward thinking each of these regions is regarding the planning for a rapid expansion of the ocean energy sector, but also the international commonality that exists between the strategies discussed. This commonality highlighted the potential for forming international synergies and collaborations to accelerate the progression of the ocean energy sector.

After the opening session, the conference ran 86 oral presentations divided into several parallel sessions grouped under three themes: Key Research Topics, Ocean Renewable Energy Development and Moving to the Industrial Scale.

Six sessions were organized under the track "Key Research Topics" to present 24 papers on different R&D aspects, namely: resource assessment and tools; array performance; tidal energy modelling, concepts and challenges; wave power concepts, components and characterization; environmental issues and performance assessment. A much larger number of papers were presented as poster. As a whole we may say that ICOE showed clearly that R&D activity on ocean energy is very much alive and covered not only the topics referred above in the oral presentations, but also site selection, numerical and experimental models, control and, to a less extent, operation and maintenance strategies and economics and marketing of ocean energy. As compared to the previous ICOE conferences, there have been a larger number of papers on tidal energy. Papers on ocean thermal energy conversion (OTEC) and salinity gradient were not present significantly, as well as papers on materials and offshore deployment issues. The weaker point in the oral and poster papers has been the much reduced impact of full-size or scale prototype tests in the sea in the presented R&D work. Indeed, and as far as the authors could find, only one paper on the airborne and underwater noise assessment at Pico plant reported work based on real data from sea trials of an existing prototype. This is a matter of relevance and worth further analysis as it shows that not sufficient information on the success and failures of ocean energy prototype deployment and tests is being passed to the wider community with the consequence that the resulting learning is insufficient. As a conclusion from the conference, the **future R&D priorities must include collation and analysis of data, and verification of device performance** (e.g. power production, environmental impact, resource interaction, survivability, reliability, etc) based on sea trials of full-scale grid-connected and partial-scale non-grid connected prototypes. **R&D should also focus more on cost-effective installation and deployment tools, including dedicated support vessels, operations and maintenance techniques,** new materials and new concepts.

"Ocean Renewable Energy Development" had 30 presentations divided into 6 sessions with the participation of technology developers covering wave and tidal energy converters, osmotic power and OTEC. A specific session was also organised to deal with a new trend, the combination of ocean energy devices with offshore wind turbines, which could benefit cost reduction due to synergies on common infrastructures. Grid integration and an update on the development of test facilities in Europe completed the review of ocean energy technologies.

"Moving to Industrial Scale" ran for three days and incorporated sessions on a range of topics, including presentations by 36 authors in seven sessions. The following is a necessarily brief review of the key points to emerge from the presentations in each session. Note that the listing of authors here is the actual order of presentations, which differed slightly from the original programme.

ECONOMICS AND COST REDUCTION

Gordon Dalton (HMRC) gave an interesting paper, one of only a few that tried to look at the economics of ocean energy, based upon what little public domain data is available. His conclusions were salutary: mid-life replacement, operations and maintenance costs and insurance can kill a project! Alex Raventos (Wave Energy Centre) described how fast marine energy could grow and tried to assess the saturation limit. His conclusion was that wave and tidal energy will become cost-comparative with other technologies between 2020 and 2030. Jochem Weber described Wavebob's three-pronged approach to viability – conceptual, technical and economic, insisting that all three were required. He demonstrated Wavebob's approach to optimizing values for levelised cost of energy, net present value and internal rate of return.

Cameron Johnstone's (University of Strathclyde) presentation focused on Nautricity's small contra-rotating horizontal axis tidal turbine. He showed that capital costs needed to fall from their current levels of GBP 8 million/MW to GBP 1.7 million/MW. Finally, Alan Mortimer described Iberdrola's involvement with the Hammerfest Strøm tidal turbine projects in Norway and Scotland.

The key conclusion from this session was that **there is still insufficient data in the public domain and research work being undertaken on costs for marine energy and cost reduction strategies.**

PLANNING, PERMITTING AND PUBLIC ACCEPTABILITY

Frank Neumann (IMI) described the OKEANOS modelling initiative and discussed legislative and regulatory requirements for ocean energy. Laura Zubiate (TECNALIA) discussed the need for Marine Spatial Planning (MSP) to secure and promote the role of marine energy amongst competing uses for marine space and resources. Julia Fernandez-Chozas (Spok) described a comparative study of public consultation and engagement for three marine energy projects, using examples from Kvitsoy in Norway, Wave Dragon in Wales and the Northwest National Marine Renewable Energy Center (NNMREC) in Oregon. Frédéric Villiers demonstrated an online GIS tool for MSP mapping developed by CETMEF

The conclusions from this session were that it is unclear whether MSP will be a benefit or a threat to future marine energy projects. With respect to public consultation, the research by Fernandez-Chozas showed that there is no substitute for early engagement and communications.

STANDARDIZATION

Melanie Nadeau, Chair of Technical Committee 114, gave a comprehensive presentation on the committee's current work on standards and technical specifications. Brian Holmes described his work on the five-stage development of marine energy devices (particularly wave and tidal current devices), before integrating these development stages with Technological Readiness Levels (TRLs), which are increasingly being used to classify technologies in terms of the development state. Neil Rondorf, who chairs the US national committee of

TC114, described the work being undertaken by US experts on development of standards and proposed some additional international collaborative research. Finally Andrew Cornett (Canadian Hydraulics Centre) talked about the guide on tidal resource assessment he had prepared for the Ocean Energy Systems Implementing Agreement (OES-IA), using examples from Minas Passage and the St. Lawrence River.

The conclusion of this session was that ***standards, guidelines and protocols will enable the marine energy industry to remain truly global*** *by promulgating common practices and language about marine energy.*

REMOVING BARRIERS AND BUILDING COMPETENCIES

Eoin Sweeney (SEAI) presented the recent publication *Marine Renewable Energy – Research Challenges and Opportunities for a new Energy Era in Europe* by the European Science Foundation. One of the interesting conclusions of this study was that marine energy could turn its low environmental impact into a competitive advantage, even with other renewable generation technologies. Juan Lopez described the € 45 million Ocean Lider project, which brings together a number of Spanish companies and research centres with the aim of reducing costs for wave, tidal and wind energy projects. Marianne Boust gave details of an IHS high-level review of renewable electricity generation, showing forecast growth of 44% (over 2,000 MW) by 2025 with **marine energy generation capacity forecast to grow to 1 GW by 2020 and to 10 GW by 2030.** Lastly, Sarah Caraher reviewed the work of the postgraduate group, INORE, which now has 460 members, most undertaking postgraduate research on marine energy in collaboration with industry.

The conclusion is that marine energy has many international collaborative activities and these are providing direction and leadership to the development of the marine energy industry. The early involvement of postgraduate students is attractive, as it will be important to see turnover of industry participants.

ACCELERATING PROGRESS

Daniela Dalton gave an interesting presentation on behalf of the Royal Bank of Scotland. She forecast a technology learning rate of 15% and said that the Bank expects marine energy to be cost-competitive with other technologies by 2020 (i.e., US$ 80-120/MWh). She said equity investment was preferred and that **banks are unlikely to show interest in projects with less than 8,000 hours in the water.** Pierre Brun reviewed Electricite de France's Paimpol-Brehat tidal project, which will use Open Hydro's 12 m diameter turbines. David Langston described the long history of the Wavegen technology – now with over 60,000 generating hours (and availability improved from 64% to 96% since 2005). Lastly, Tim Ramsey of the US Department o Energy detailed the use of TRLs to determine the maturity of marine energy projects, particularly with regard to their 2010 solicitation (which led to US$ 37 million being awarded to 27 projects).

The conclusion from this session was that there is no faster alternative route to commercialization than that provided by 'time in the water' for operating power plants.

LESSONS LEARNT FROM OTHER SECTORS

Neil Rondorf chaired a very interesting series of nine brief presentations by suppliers to other industries, offering equipment or services, ranging from grout or wind turbines to anti-fouling coatings for submerged devices. It was clear that there is a ready supply chain that can supply significant services to device and project developers.

POLICIES AND NATIONAL INITIATIVES

The final session chaired by Nathalie Rousseau (EU-OEA) was a very useful set of presentations of the policies and initiatives being used to promote and accelerate marine energy in Spain, the United Kingdom, France, Portugal and Canada. It was clear that there are many policy instruments available and many governments are developing approaches with specific expectation that marine energy can be a significant part of their clean energy strategies.

ROUND TABLE WITH KEY INDUSTRIAL PLAYERS

At the conclusion of the ICOE 2008 event in Brest, the wrap up panel of ocean energy sector leaders concluded that the emerging interest by utilities and by a few integrator/manufacturers was a good sign that ocean energy could move ahead. Fast forward to Bilbao in October 2010 and the sector has seen numerous investments by utilities and by a growing list of potential manufacturers, more full-scale trials of technology and the sector-focusing announcements of the potential 1.2GW in the 10 leases in Pentland Firth. So, a clear picture of the essential pathway for the sector emerged when Sue Barr, technology developer (Open Hydro), Jochen Weillep (Voith) and Philippe Gilson (Alstom) as integrator/maufacturers, Joe Hulm (International Power) and Luis Gomez Chavarria (Iberdrola Renovables) as power project developers, all engaged in a concluding panel, chaired by Chris Campbell (OREG).

The panel noted that **the 2020 aspirations of 2-4GW installed that had come from a number of presentations was achievable if the experience with wind power manufacturing and development is to be repeated.** However, they expressed an urgency to achieve a transition from research at the demonstrations scale to the accelerated learning from piloting power plants.

The message was one of focusing on demonstrating MWh of electricity produced by ocean energy. It was clear that **even as only a few generators have achieved that target, work must focus on demonstrating pilot power plants as soon as possible.** All agreed that planning for the permitting, financing, installation, operations and maintenance of array-scale pilots has to begin even as the individual generator trials are underway. Panellists reinforced the concept offered up by Iberdrola earlier in the conference that an effective development plan has to be working on 1 MW, 10 MW and commercial scale initiatives at the same time, aiming to incorporate the lessons learnt from one scale into the next. This recognises the challenge and time required to permit marine projects and to finance any move to larger scale, and fits with the conviction that technical and operational challenges will be solved at each of these phases. It also recognises that the interest of governments, utilities, manufacturers, investors and the supply chain can only be mobilised if they are working toward a target that is representative of an industrialised approach.

Addressing the need to accelerate this development, the panellists highlighted the need to focus assets on the path forward, and to avoid duplication. Testing in any jurisdiction should facilitate technology advance anywhere. The issue of the growing commitment to demonstration centres over the last two years led to a discussion of how these could take on unique roles rather than simply replicate the European Marine Energy Centre (EMEC). The discussion advanced the concept that these common infrastructure facilities could be better focused as development centres or incubators since they have the potential to solve the major impediments to moving forward, those of access to permitted ocean, and access to grid. The importance of coordination between all of them and dissemination of key outcomes can avoid duplication and accelerate overall progress since many advances are potentially widely applicable. Also their work should be focused on the needs of utilities in addition to technology developers, recognizing the fact that market-pull is critical to the 10MW+ generations of projects. Their early participation is essential so that they can become comfortable ahead of these major investments.

It was perhaps this discussion that set the closing challenge at ICOE 2010. **Can the creation of the development centres in Ireland, France, Spain, Canada and the US be used to create some forms of Marine Energy Parks or incubators?** Should these share the burden of permitting, grid access, environmental monitoring and marine operations and create an open pathway ahead of the power project and technology development plans? If the panel set a challenge to be reported on at ICOE 2012, it would be to show how these incubators are catalysing a phased development of power development projects as the prototype "power plants" for this sector.

Round table: Chris Cambpell (OREG),Jochen Weillep (Voith), Philippe Gilson (Alstom), Sue Barr (Open Hydro), Luis Gomez-Chavarria (Iberdrola Renovables) and Joe Hulm (International Power).

Participants in the closing session: Antonio Sarmento (Wave Energy Centre), Oscar Zabala (Basque Government), Jose Luis Villate (Tecnalia), Thierry D'Estaintot (European Commission), Jochen Bard (Fraunhofer IWES), John Huckerby (OES-IA)

ICOE 2010 attracted the top companies in the world from the ocean energy sector with more than 600 delegates and around 400 visitors to the exhibition and parallel events. These figures made ICOE 2010 the world's largest ocean energy event to date.

Future Research and Development priorities must include collation and analysis of data, and verification of device performance based on sea trials of full-scale grid-connected and partial-scale non-grid connected prototypes.

There is still insufficient data in the public domain and research work being undertaken on costs for marine energy and cost reduction strategies.

Test facilities should be better focused as development centres or incubators where technology developers and utilities are catalysing a phased development of power development projects as the prototype "power plants" for this sector.

ICOE 2010 IN FIGURES

Venue and Date: **Bilbao Exhibition Centre; 6-8 October 2010**

Organisers: **Ente Vasco de la Energía and Tecnalia**

Main sponsor: **Iberdrola**

Other sponsors: **Ormazabal, Vicinay Cadenas, Sener, Ingeteam and Euskaltel.**

Partners: **OES-IA, EU-OEA and the Basque Energy Cluster**

Delegates: **603 from 32 different countries**

Majority of industrial participants (51%);

Public Bodies (7%);

Universities and Research Centres (42%)

Oral presentations: **94**

Visual presentations: **78**

Exhibition organised by EU-OEA:

35 exhibitors from 10 different countries

Around 200 visitors (in addition to the conference delegates)

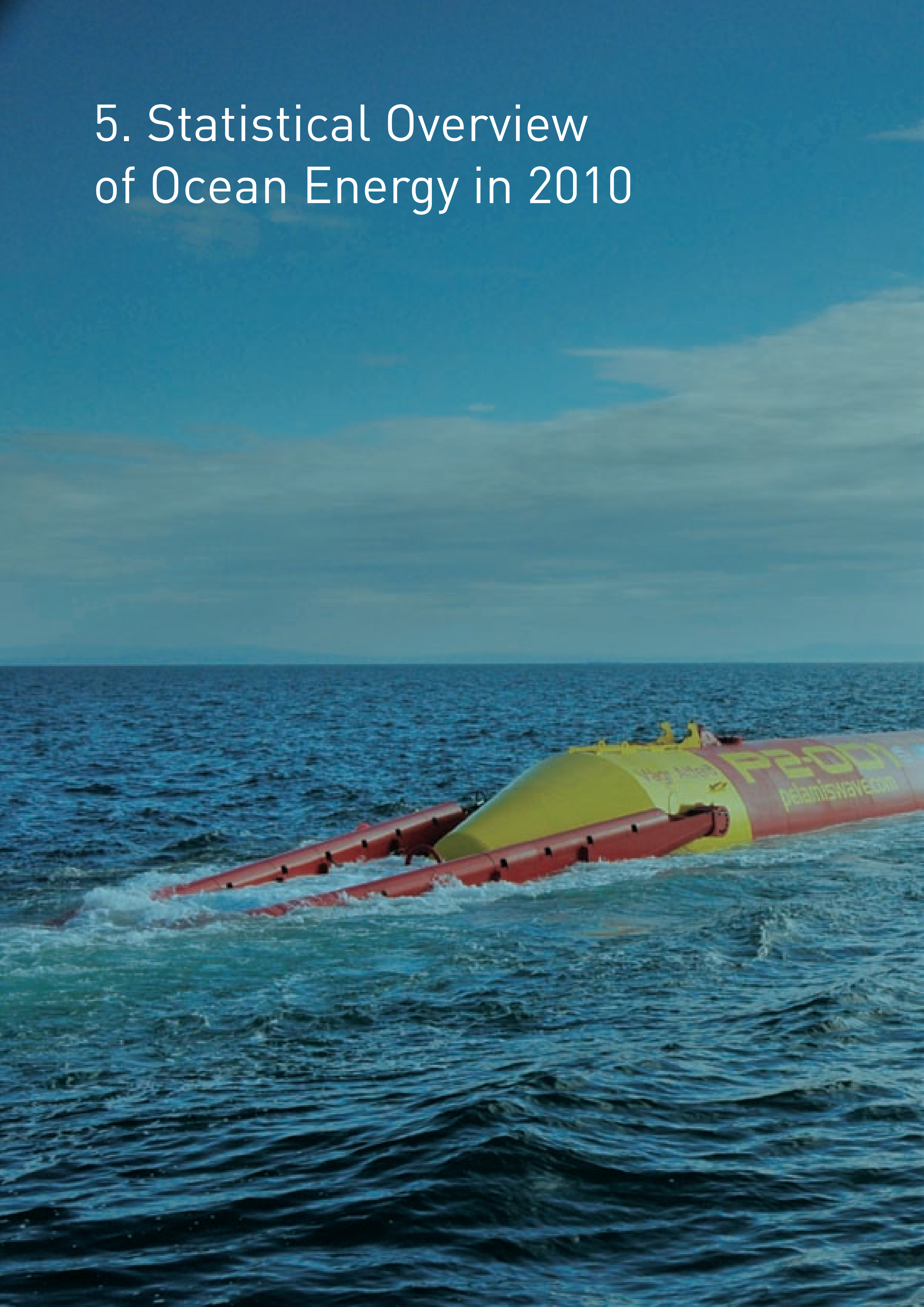
More information: **www.icoe2010bilbao.com**

Next ICOE: **Autumn 2012 in Dublin organised by SEAI (Sustainable Energy Authority of Ireland)**

ICOE2012

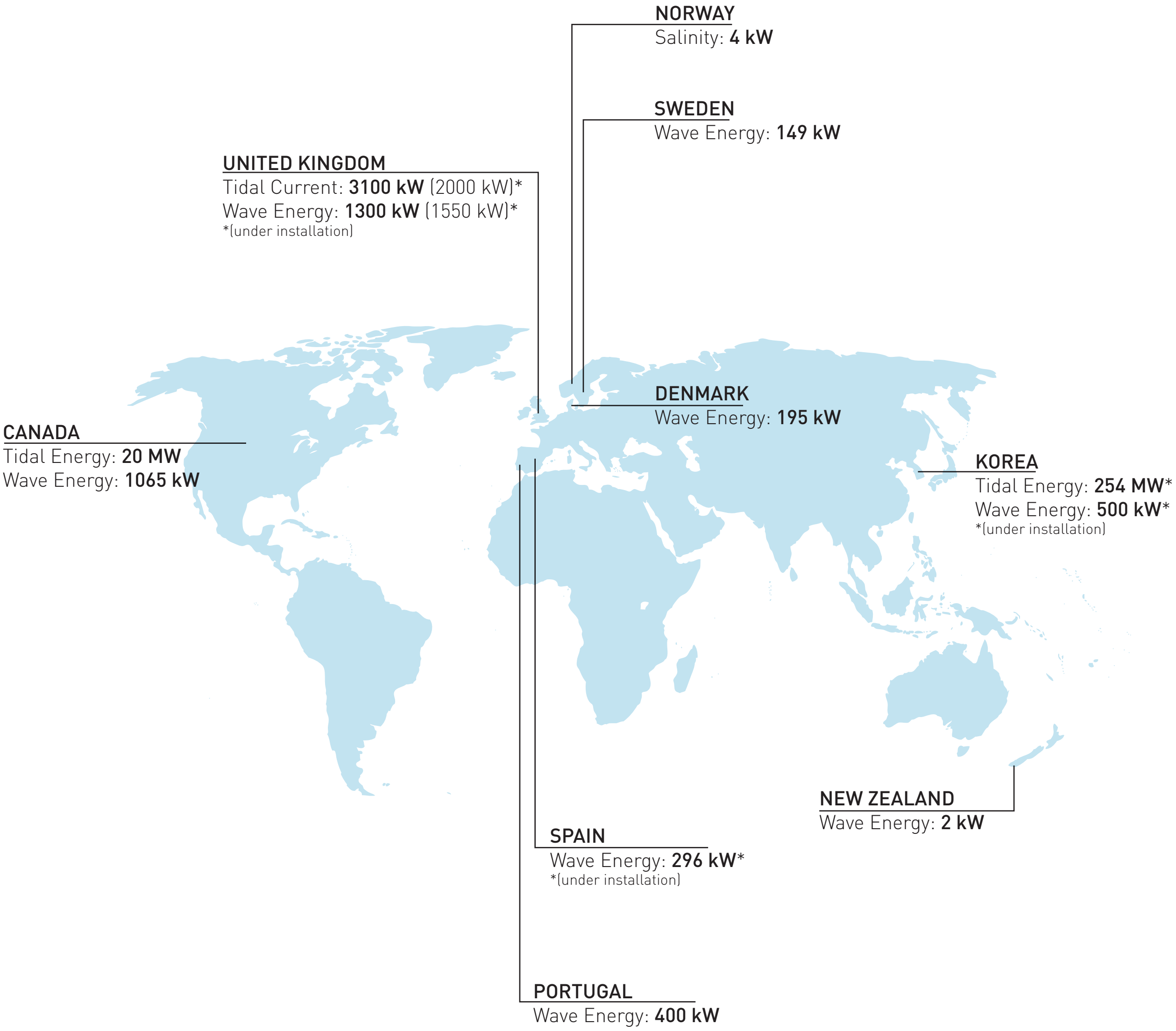
Eoin Sweeney thanked the Committee for the invitation to Ireland to host ICOE 2012. In accepting the invitation, he acknowledged the challenge of organising an event that will maintain the quality and enthusiasm that was evident at ICOE 2010. He congratulated EVE and Tecnalia and welcomed their continued involvement through the organising Committee for 2012. He stressed the commitment that the Irish authorities have shown to the development of ocean energy and the wholehearted support that exists across many agencies, to ensure that ICOE 2012 will be a success and welcomed all the participants to Dublin in October 2012.

5. Statistical Overview of Ocean Energy in 2010



The information provided in this section refers to the year 2010 and was compiled from information provided by each delegate member.

5.1 Worldwide Ocean Power Installed Capacity (kW)



5.2 Electrical Utilities Involved in Research & Development and Demonstration

Country	Utility	Type of involvement
Canada	BC Hydro	Assessment of resource, integration of hydrokinetic technologies, standards involvement
	Nova Scotia Power Inc.	Site developer, standards involvement, transmission to test facility
Denmark	Thy-MorsEnergi	Involved in the Wave Star Energy prototype grid connection
Ireland	Electricity Supply Board	Through its subsidiary, ESBI, the ESB has an active programme of activities designed to support the introduction of OE into its generation mix. ESBI is also an active partner in developing the AMETS open ocean wave test facility.
	Bord Gais Eireann (BGE)	BGE has invested in a number of wave energy technologies and is providing technical and engineering support to the entities involved.
Korea	Korea Water Resources Corporation	Construction of Shihwa tidal barrage power plant
	Korea East-West Power Co., Ltd.	Operation of Uldolmok tidal current pilot plant
	Korea Western Power Co., Ltd.	Feasibility study on Garorim tidal barrage power site
	Korea Hydro and Nuclear Power Co., Ltd.	Feasibility study on Incheonman tidal barrage power site
	Korea Midland Power Co., Ltd.	Feasibility study on Ganghwa tidal barrage power site
	Hyundai Heavy Industry Co., Ltd.	Development and full-scale demonstration of tidal current device
	Ocean Space, Inc.	Development and part-scale demonstration of tidal current device
	Taekyung Industry Co., Ltd.	Development and part-scale demonstration of wave energy device
	Ecocean Co., Ltd.	Development of hydro turbine system utilizing discharged cooling water

Sweden	Vattenfall AB	R&D
	Fortum AB	R&D
	Statkraft AS	R&D
	Göteborg Energi AB	R&D
	Falkenberg Energi AB	R&D
Mexico	Comisión Federal de Electricidad	Measuring currents and waves
Norway	Hafslund AS	Supports tidal energy concept
	Statkraft AS	Develops osmotic power and runs a large R&D program in Ocean Energy
	Tussa Kraft AS	Supports wave energy concept SeaBased
	Hålogaland Kraft AS	Supports tidal energy concept Hydra Tidal
	Lofotkraft Holding AS	Supports tidal energy concept Hydra Tidal
	Hammerfest Energi AS	Part owner of Hammerfest Strøm AS
New Zealand	Todd Energy	Acquired 30% of Crest Energy Kaipara Limited in 2009
Portugal	EDP	Technology demonstration or project development
Spain	IBERDROLA	R&D, technology demonstration and project development.
UK	EON	Technology demonstration
	Scottish Power	Technology demonstration & Project development
	SSE Renewables	Technology demonstration & Project development
	RWE nPower	Project development
	EdF	Project development
	International Power	Project development
	ESBI	Technology demonstration & Project development

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