OES-IA

ANNUAL REPORT 2009

International Energy Agency
Implementing Agreement
on Ocean Energy Systems

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IEA | OES
Ocean Energy Systems

2009 ANNUAL REPORT – OES-IA DOCUMENT A09

PUBLISHED BY the Executive Committee of the OES-IA

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DESIGNED BY P-06 ATELIER E AMBIENTES E COMUNICAÇÃO LTD

CIRCULATION 1000 EXEMPLARS

PRINTED BY TEXTYPE

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Chairman's Message

Welcome to the 2009 Annual Report of the Ocean Energy Systems Implementing Agreement (OES-IA) of the International Energy Agency (IEA). The report provides an overview of the activities and achievements of the Executive Committee (ExCo) of the OES-IA, the four Annexes (work programmes) currently in progress and of its member and observer countries.

The primary vision of the OES-IA, which is in its second five-year term, is "to realize cost-competitive, environmentally sound ocean energy on a sustainable basis to provide a significant contribution to meeting future energy demands". It aims to achieve this vision through a five-year strategy, which reached its midpoint in 2009. The Executive Committee's actions to achieve its five-year strategy were reviewed with the IEA's Renewable Energy Working Party (REWP) at a meeting in Paris on 24-25 March 2009. I am pleased to report that the REWP endorsed the ExCo's activities to date and its proposed plan for meeting its remaining objectives. The mid-term report can be found at the OES-IA website (www.iea-oceans.org).

Membership of OES-IA has continued to grow during 2009. Australia became the 17th country to join in early 2009 and, before year-end, the Republic of Korea is completing the membership application process to becomes a member in early 2010. South Africa is also in the process of joining and, during 2009, the ExCo formally invited Russia and Finland to join OES-IA. In September I travelled to Harbin in NE China to present a paper at the International Symposium on Ocean Energy and met with Chinese Government officials. A formal invitation for China to join the Implementing Agreement was sent on 10 September 2009. France, Brazil and Chile are also considering membership and have sent observers to ExCo meetings in the past. Any country interested in joining the OES-IA can send an Observer, by invitation, to ExCo meetings to provide an understanding of the ExCo work programme, benefits and obligations of membership.

During 2009 OES-IA's research and development activities have continued through its Annexes. In March 2009 the ExCo approved the establishment of a new Annex entitled "Assessment of Environmental Effects and Monitoring Efforts for Ocean Wave, Tidal and Current Energy Systems". Annex IV recognizes the importance of the management of environmental effects of marine energy converters, not only through the permitting process but also during the lifetime of the converters. The Annex grew out of an expert workshop, sponsored by the OES-IA, in Messina, Italy, in October 2007. This 3-year Annex is being led by the US Department of Energy and carried out jointly by the US Minerals Management Service and the Federal Energy Regulatory Commission. The work programme will lead to a global database of environmental effects and mitigation strategies, case studies and a comprehensive report, which will be valuable to all marine energy project developers and regulatory authorities. So far, seven countries have joined this collaborative effort.

Annex III continued its work on the integration of ocean energy plants into distribution and transmission grids. During the year Annex III produced two reports as part of Work Package 1, which characterized the electrical outputs of marine energy converters and looked at interconnection issues. Before year-end the ExCo approved the completion of a third report (from Work Package 2) on best practices for characterizing different marine energy generation technologies and extended the Annex to end-2010 to allow the completion of Work Package 3, which will be a set of case studies, illustrating transmission/distribution network modelling of integration of marine energy converters.

Annex II – Development of Recommended Practices for Testing and Evaluating Ocean Energy Systems – drew to a close. Five reports are currently being finalized and will be available on the OES-IA website in early 2010. Dr. Teresa Pontes led a workshop on the activities of Annex II in association with an international ocean energy conference held in Lisbon in early November.

Dissemination activities undertaken under Annex I included the publication of reports from Annexes II and III, a newsletter and a significant number of updates and new uploads to the OES-IA website. ExCo members also attended and presented papers on a range of topics at conferences in Bilbao, Washington, Calgary, Uppsala, Harbin, Lisbon, Cadiz and Paris.

OES-IA ExCo members have a number of formal and informal links to other international and regional projects and initiatives. These include formal liaison with the International Electrotechnical Commission's Technical Committee 114, which is establishing international standards for marine energy converters. Members are also involved as research partners, Steering Committee members and reviewers of the

European Union-funded EquiMar consortium research programme, which is establishing a set of protocols for marine energy testing and evaluation. A small number of members are also engaged as authors of the Intergovernmental Panel on Climate Change's Special Report on Renewable Energy Sources and Climate Change Mitigation. This Special Report is due for publication in early 2011 and includes a chapter on ocean energy.

OES-IA finances are currently strong and the Executive Committee voted to use some of these resources for two new initiatives, which were initiated in late 2009:

1. An "International Vision for Ocean Energy" – a brochure setting out the current status, progress, opportunities for and barriers to uptake of ocean energy. This brochure will be completed and published during 2010.
2. An inventory of full-scale ocean test sites. The development of test sites for deployment and development of marine energy converters is an unusual characteristic of the ocean energy industry.

In this Annual Report we have continued the practice of including a number of overview papers, which first appeared in the 2008 report. The previous theme was the status of marine energy technologies. The theme in this report is barriers to uptake of ocean energy technologies. The five papers presented here address barriers from competition, testing protocols and development of standards to regulatory issues, such as permitting and environmental compliance.

For the first time this Annual Report also includes a statistical overview of ocean energy in 2009. The ExCo recognizes the need for and value of a set of reliable statistical data and the overview included here is a first attempt to collate information on Research & Development (R&D) investment, installed capacity and involvement of electrical utilities in ocean energy investment. Such information is difficult to gather, even in the OES-IA member countries, but we plan to expand this feature to establish future annual report as an authoritative source of information on the international growth of ocean energy.

2009 has seen the growth of ocean energy internationally. New technologies and new projects are being announced regularly and the country reports presented here demonstrate the breadth of activities. Many projects operate below the radar of the international press, so there is some very useful information on specific projects in country reports in Chapter 5. Most projects are still at an early stage but 2009 has seen the first full year of operation of MCT's SeaGen tidal turbine, the commissioning of the Nova Scotia tidal test centre and the deployment of Aquamarine's Oyster surge device at the European Marine Energy Centre.

The first competitive bidding round for permits for marine energy projects closed in the UK, although awards have not yet been announced. Governments continue to be major investors in marine energy R&D but major electrical utilities and international energy companies are beginning to invest more broadly and deeply in marine energy. Undoubtedly investment in marine energy technologies and projects has been delayed or deferred by the global recession. Despite this economic uncertainty, it is encouraging to see that many research projects and many investments have continued unabated.

Although a replacement for the Kyoto Protocol was not successfully negotiated in Copenhagen, the issues of climate change, greenhouse gas emissions reductions and energy efficiency are clearly on the international agenda. Marine energy should be a beneficiary of these interests, insofar as it promises to be a renewable, sustainable and emissions-free source of energy. Increasing concerns about freshwater supplies mirror international shortages of energy. Marine energy may provide a future source of freshwater.

I would like to thank all the members of the Executive Committee for their time and commitment during 2009. There have been some challenges during the year, which have been met, leaving the OES-IA in a stronger operating position going into 2010. I would also like to thank the IEA's Legal Office for their advice, the IEA Secretariat and the REWP for their continued support for OES-IA activities. Lastly, I would like to thank my Vice-Chairs for their wise advice and the OES-IA Secretariat for her efforts during 2009.

Dr. John Huckerby
Aotearoa Wave and Tidal Energy Association
OES-IA Chairman 2009-2010

Executive Summary

This 2009 Annual Report reviews the progress of activities in the Implementing Agreement on Ocean Energy Systems (OES-IA) of the International Energy Agency (IEA) during the year 2009. 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 IEA provides a framework for 42 international collaborative energy research, development and demonstration projects known as Energy Technology Agreements. These Implementing Agreements have been created to encourage collaborative efforts to meet the main challenges of energy policies: ensuring energy security and addressing climate change issues in a cost-effective way.

The Ocean Energy Systems Implementing Agreement (OES-IA) is a collaborative venture among various member countries and the European Commission. As of December 2009, those members are Portugal, Denmark, United Kingdom, Japan, Ireland, the European Commission, Canada, the United States of America, Belgium, Germany, Norway, Mexico, Spain, Italy, New Zealand, Sweden and Australia, ordered by sequence of joining the Agreement.

Established in October 2001, the OES-IA is now in its second 5-year term. During 2009 the mid-point of its current term was reached and a progress report on the achievements to date and the ongoing work was delivered by the Chairman of the Executive Committee (ExCo) to the IEA's Renewable Energy Working Party (REWP) in Paris.

This annual report presents the 2009 activities and outputs of the OES-IA ExCo, which now comprises 4 Annexes (or work programmes).

Chapter 1 describes the basic organization, membership, work programmes and financial position of the OES-IA. Chapter 2 describes the activities and accomplishments of the ExCo during 2009, whilst Chapter 3 provides reports from each of the Annexes (work programmes) that are currently active.

In Chapter 4, the ExCo has again invited industry experts to prepare articles on specific topics. In the 2008 Annual Report, six authors gave their views on the current status of ocean energy technologies. In this Annual Report, the ExCo decided to focus on a theme of 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. Again, five recognized industry experts have responded with wide-ranging papers on these themes.

The marine renewable energy roadmapping activity, being undertaken by the United Kingdom Energy Research Centre (UKERC) in the UK, has been a notable example of a focused and coherent approach to technology development in the marine sector. The first article "***The Opportunity and Challenge for Ocean Energy as Part of Energy System Decarbonisation: the UK Scenario"*** presents a number of significant technological challenges that ocean energy faces in order to reach fully commercial status. The article describes a scenario model for the UK, highlighting the potentially important role of ocean energy technology acceleration in the UK energy system from now until 2050.

The document "Ocean Energy: Development and Evaluation Protocol" published in 2003, in Ireland, jointly by the Marine Energy Institute and the Hydraulics and Maritime Research Institute (HMRC) describes a development and evaluation protocol that has been specifically adapted for the advancement of wave energy devices, from initial concept to its final demonstration. The article "***Marine Energy Device Development: A Structured Programme to Mitigate Technical & Financial Risk"*** presents a recommendation for a five-stage approach and decision procedure, which will reduce the financial and technical risks during the development of wave and tidal current technologies.

As ocean energy technologies develop, the nascent ocean energy industry is finding synergies and opportunities with other marine, electrical and engineering activities, such as engineering for oil or gas platforms, floating offshore wind, offshore aquaculture and others. Exploring these synergies can be a valuable contribution to accelerate the deployment of ocean energy, which is the topic of the article "***Ocean Energy as Ocean Space Use – Only Conflicts or Also Synergies?".***

In addition to the technical challenges for harnessing the energy of ocean waves, a major concern of project developers are non-technical challenges or barriers not directly related to the technology. Large-scale implementation will face a considerable number of challenges, commonly summarised as “non-technical barriers”, including regulatory processes for licensing, permitting and leasing of space and resources. The article “***Overview of Global Regulatory Processes for Permits, Consents and Authorization of Marine Renewables”*** provides an international overview of these barriers and specific solutions.

In the present stage of ocean energy development there is a need to implement standards for monitoring device performance, standard analytical techniques, presenting results and safety standards in relation to structure, personnel and electrical system. The OES-IA has already initiated some work in this area and outlined recommended practices, under the Annex II work programme. A number of organizations are now engaged in developing standards and protocols, of which the most globally significant is the work of the International Electrotechnical Commission Technical Committee 114 (IEC/TC 114). The last article on ***“The Standardization of Marine Renewable Energy Conversion Systems”*** has been written by the Chair of Technical Committee 114 (TC 114), Ms. Melanie Nadeau.

Chapter 5 presents the national activities of the OES-IA member countries and other potential member countries organised under three key topics i) ocean energy policy, ii) research and development and iii) technology demonstrations during the year. Further, based on information from delegates, a statistical information for 2009 was compiled and presented on chapter 6 covering i) Level of research & development and demonstration investment, ii) Worldwide ocean power installed capacity and iii) Electrical utilities involved in Research & Development and Demonstration.

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

1. The Ocean Energy Systems Implementing Agreement

1.1 Vision, Mission and Strategic Objectives

The International Energy Agency (IEA) provides a framework for more than 40 collaborative programmes, known as Implementing Agreements, in the areas of renewable energy, hydrogen, fossil fuels, fusion power, end use and cross-cutting activities for technology research, development, demonstration and deployment. The Implementing Agreement on Ocean Energy Systems (OES-IA) is one of ten IEA Implementing Agreements within the renewable energy domain (Figure 1.1). The OES-IA was set up in October 2001 and is now over halfway through its second 5-year term.

The OES-IA programmes bring 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 (Figure 1.2). The OES-IA covers all forms of energy generation, in which sea water forms the motive power, through its physical and chemical properties. It does not presently cover offshore wind generation, since sea water is not the motive power.

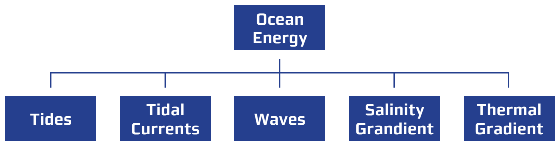

Figure 1.2: Principal Forms of Ocean Energy

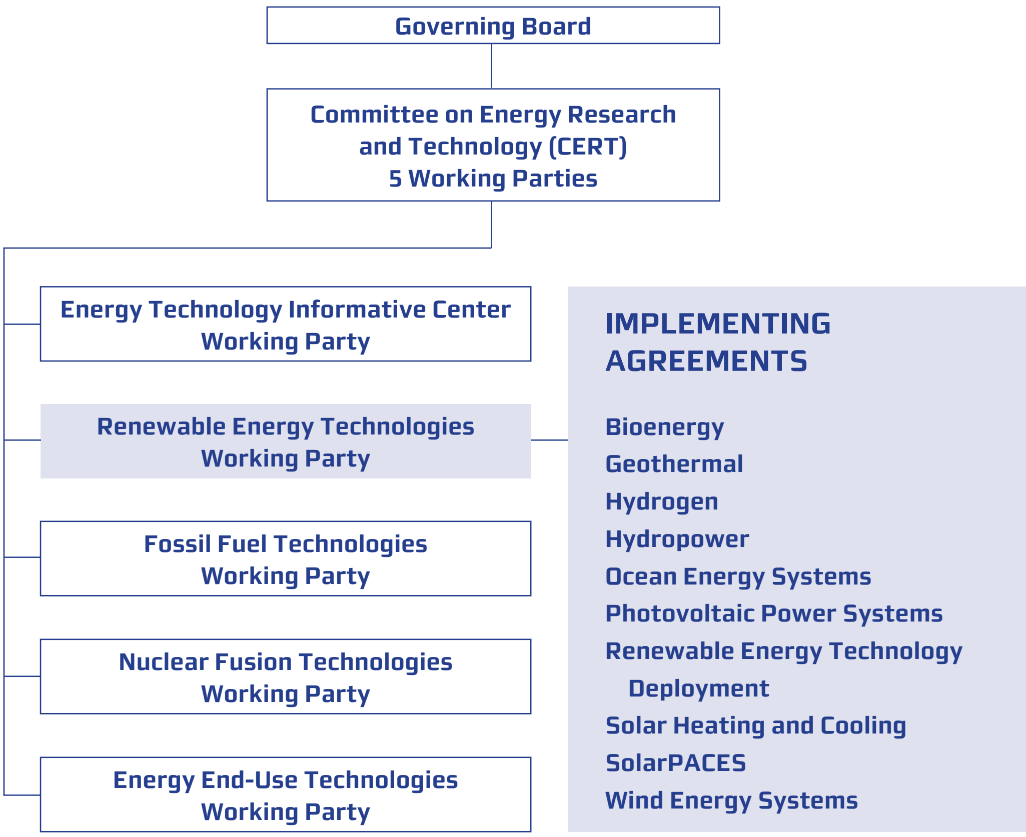

Figure 1.1: Renewable Energy Implementing Agreements in the IEA

The initial (2001 – 2006) Strategic Plan identified that the focus for the OES-IA would be ocean wave and tidal current technologies. To reflect the recent growth in scale and scope of activities in ocean energy research and development, the OES-IA determined to revisit the vision, mission and strategic objectives of the Implementing Agreement (IA), whilst preparing the next five-year strategy. The 2007 – 2011 Strategic Plan altered the initial Vision, removing reference to the capacity of energy demand to be met by ocean energy and the exclusion of other uses of ocean energy, such as desalination. This change recognized a broader range of end uses for ocean energy, beyond electricity production, and that marine energy may displace demand for energy produced through other means. It also recognised that the amount of ocean energy that could be produced by 2020 was uncertain and the inclusion of a realistic target in the vision statement was premature.

The modified Vision and the Mission statements are as follows:

- **OES-IA 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.

- **OES-IA 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.

  The proposed Strategic Objectives set for 2007 – 2011 are as follows:

  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, development 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.

In 2009, a mid-term report was prepared on the progress of the Executive Committee (ExCo) to meet its 5-year Strategic Plan and was presented to the Renewable Energy Working Party Group (REWP) in Paris. This initiative is a way of strengthening communications and exchange of views on current and emerging issues between REWP and OES-IA. The report, which is available at the publications area on the website (www.iea-oceans.org), presents the activities carried out in the current term, in the period from November 2006 to March 2009, current issues facing the IA and solutions being enacted to address them. The report also sets out the Executive's plans to fulfil the remainder of the objectives of its current Strategic Plan by October 2011.

The REWP was supportive of the ExCo's activities and initiatives to continue to deliver its plan.

1.2 Membership

Membership of the OES-IA is by invitation (from the IEA Secretary) to country governments. The ExCo has an active interest in securing new members and the OES-IA has continued to show steady growth during

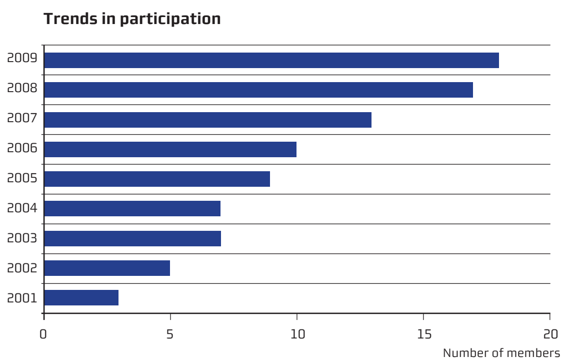

Figure 1.3: OES-IA Membership Growth

Year	Country	Contracting Party
2001	Portugal	Instituto Nacional de Engenharia, Tecnologia e Inovação (INETI)
2001	Denmark	Ministry of Transport and Energy, Danish Energy Authority
2001	United Kingdom	Department of Energy and Climate Change (DECC)
2002	Japan	Saga University
2002	Ireland	Sustainable Energy Ireland (SEI)
2003	European Commission	Commission of European Communities
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
2007	Norway	The Research Council of Norway
2007	Mexico	The Government of Mexico
2008	Spain	TECNALIA
2008	Italy	Gestore dei Servizi Energetici (GSE)
2008	New Zealand	Aotearoa Wave and Tidal Energy Association (AWATEA)
2008	Sweden	Swedish Energy Agency
2009	Australia	Oceanlinx

Table 1.1. Contracting Parties to the OES-IA (status: Dec. 2009)

its nine years of operation and this trend seems set to continue (Figure 1.3).

Australia became the newest member of the OES-IA at the beginning of 2009 but the Government of the **Republic of Korea** and the Government of **South Africa** accepted the invitation to join the OES-IA by the end of the year, which will bring the number of members to nineteen in early 2010. During the year the OES-IA Executive Committee officially has invited **Russia**, **Finland** and **China** to become members. **France, Netherlands** and **Chile** were invited to join during 2008 but still have to finalize the membership procedures.

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. Consequently, representatives to the OES-IA Executive Committee cover a wide range of disciplines and interests in ocean energy, ensuring a wide diversity of views and solutions (Table 1.1). Governments also nominate alternates, who may represent the government at ExCo meetings, if the nominated representative is unavailable. This further diversifies the representation of interests on the ExCo.

In 2009 there were also personnel changes among the Contracting Party representatives and Alternates (See 2009 Executive Committee for Representative Members, Alternate Members, and Operating Agent representatives who served in 2009).

1.3 Work Programme

The mechanisms of collaboration have been developed through the activities of specific work programmes (known as Annexes to the OES-IA work programme). At the end of 2009, the work programme of the OES-IA comprises four Annexes (Table 1.2).

Members of OES-IA are invited to participate in all Annexes but each member is free to limit its participation to those tasks that have a programme of special interest, except for the mandatory Annex I (Table 1.3).

In Annex I, participants assign specific resources and personnel to carry out the work. The other tasks are based on cost-shared and task-shared activities.

Annex I	**Review, Exchange and Dissemination of Information on Ocean Energy Systems**
OA:	INETI/LNEG – PORTUGAL
Duration:	From 2001 (indefinitely)
Contribution:	Obligatory contribution; in-kind effort
Annex II	**Development of Recommended Practices for Testing and Evaluating Ocean Energy Systems**
OA:	Ramboll – DENMARK
Duration:	2002-2003; 1st Ext 2004-2006; 2nd Ext 2007-2009
Contribution:	3,000 € plus in-kind effort
Annex III	**Integration of Ocean Energy Plants into Distribution and Transmission Electrical Grids**
OA:	Powertech Labs – CANADA
Duration:	2007 – 2009; 1st Ext 2009 – 2010
Contribution:	3,000 € plus in-kind effort
Annex IV	**Assessment of Environmental Effects and Monitoring Efforts for Ocean Wave, Tidal and Current Energy Systems**
OA:	Department of Energy – USA
Duration:	2009 – 2011
Contribution:	5,000 € by each participant each year for a period of 3 years

Table 1.2. OES-IA Current Annexes (status: Dec. 2009)

Country	**Annex I** *Collection and Dissemination of Information*	**Annex II** *Development of Recommended Practices*	**Annex III** *Integration into Electrical Grids*	**Annex IV** *Assessment of Environmental Effects*
Portugal	X	X		
Denmark	X	X		
United Kingdom	X	X	X	X
Japan	X			
Ireland	X	X	X	X
European Commission	X			
Canada	X	X	X	X
United States	X	X		
Belgium	X	X		
Germany	X			
Norway	X	X		X
Mexico	X	X		
Spain	X	X	X	X
Italy	X			
New Zealand	X		X	X
Sweden	X			X
Australia	X	X		

Table 1.3. Participants in each Task of the OES-IA Work programme (status: Dec. 2009)

1.4 Financial Status of the OES-IA

The Wave Energy Centre in Lisbon, Portugal, manages the OES-IA common fund. The common fund provides financial resources for managing the work and activities of the ExCo and the Secretariat. It additionally covers the costs of dissemination activities under Annex I (editions of documents and newsletter).

Membership of OES-IA requires an annual contribution of 7,000 Euros by each member country. The subscription fee enables the member to vote on all issues before the ExCo, which meets twice a year.

The OES-IA common fund was audited by Moore Stephens audit company in Portugal in January 2010. Details on the income and liabilities are summarised in Table 1.4.

	December 31, 2009
Current assets	
Accounts receivables	
Membersheep fees	28 000.00
Bank account	163 289.04
Total assets	191 289.04
Current liabilities	
Accounts payables	
Expenditures 2009	(41 767.91)
Total liabilities	(41 767.91)
Net assets	149 521.13

Table 1.4 – Balance Sheet of the OES-IA common fund as of December 31, 2009

2. Accomplishments in 2009

2.1 Highlights in 2009

The milestones of the 2009 work programme can be summarised as follows:

- **During 2009, the number of Contracting Parties has reached a total of seventeen:** Australia became the newest member in 2009. Korea and South Africa also accepted to join at the start of 2010. China and Finland were officially invited by the ExCo during the year.

- **Successful submission of the OES-IA mid-term report:** The Chairman delivered a mid-term report to the IEA Committee on Energy Research and Technology (CERT) and presented it to the REWP at its 55th meeting in Paris (24 March 2009). The REWP was supportive of the ExCo continuing to deliver to its current Strategic Plan.

- **Commissioning of Annex IV:** A formal invitation for participation in the approved *Annex IV – Assessment of Environmental Effects and Monitoring Efforts for Ocean Wave, Tidal and Current Energy Systems* was sent to all members, requesting a letter of commitment from the interested countries: US, Canada, Spain, Ireland, New Zealand, Sweden and Norway have committed to join the project and, in April 2009, the study was commissioned and the work programme began.

- **Two new publications launched in 2009**: a *Wave Data Catalogue*, prepared by Instituto Nacional de Engenharia, Tecnologia e Inovação (INETI), and the report, *Ocean Energy: Global Technology Developmental Status*, prepared by Powertech Labs Inc, were published.

- **OES-IA legal text:** The ExCo unanimously approved an amended version of the OES-IA legal text, the contractual document which sets out the terms and conditions by which the Implementing Agreement is governed.

- **New proposal "International Vision for Ocean Energy"**: The ExCo approved to prepare an OES-IA document with the intention to summarise the position, direction and opportunities for ocean energy in the future.

- **OES-IA Seminar:** The ExCo approved a proposal for an OES-IA sponsored seminar on the "*Business Financing Of The Wave And Tidal Stream Secto*r" in conjunction with the 3rd International Conference on Ocean Energy (ICOE) to be held in Bilbao on 6 – 8 October 2010. The seminar will most likely precede the conference (i.e. 4 – 5 October 2010).

- **Initiation of a new collaborative activity:** An inventory of open sea test centres/pilot zones was to be developed during 2009.

2.2 Executive Committee Meetings

The OES-IA work programme is co-ordinated by the ExCo, which comprises representatives of all the participants in the Implementing Agreement. The ExCo is the decision-making body of the IA. Under the OES-IA, the ExCo develops a Strategy and Strategic Plan and establishes collaborative work programmes to deliver this Plan. The ExCo meets twice a year. In 2009, ExCo meetings were held in Bilbao, Spain (30 – 31 March 2009), and in Oslo, Norway (4 – 5 September 2009).

16th OES-IA ExCo meeting group in Bilbao, Spain

16th ExCo meeting

30-31 March 2009, Bilbao, Spain

This meeting was hosted by TECNALIA, the Spanish contracting party to the OES-IA, in Bilbao, Basque region of Spain, with 33 participants. The alternate member from Spain, José Villate, was the local organiser of the meeting. A special session of the meeting was dedicated to Ocean Thermal Energy Conversion (OTEC) and the Delegate from Japan, Dr. Yasuyuki Ikegami, gave a presentation on this topic.

17th OES-IA ExCo meeting group in Oslo, Norway

17th ExCo meeting

4-5 September 2009, Oslo, Norway

The 17th ExCo meeting was held in Oslo, Norway, with 28 participants. This meeting was hosted by Statkraft. The Delegate member from Norway, Mr. Petter Hersleth, was the local organiser of the meeting. A special session on this meeting was dedicated to Submarine Geothermal Energy and the Delegate from Mexico, Dr. Gerardo Hiriart, gave a presentation on this topic.

At the 17th ExCo meeting, the ExCo approved plans for its 2010 meetings to be held in New Zealand and Ireland. Meetings for 2011 – 2012 are already being planned.

ExCo meetings planned for 2010		
Meeting:	**ExCo 18th Meeting**	**ExCo 19th Meeting**
Hosted by:	New Zealand	Ireland
Date:	22-23 April 2010	29 Sept – 1 Oct 2010
Local:	Wellington, New Zealand	Dublin, Ireland

2.3 New Initiatives

The following tables presents the facts of the launched projects during the year.

Brochure "International Vision for Ocean Energy"	
Motivation	Countries active in the ocean energy sector have defined ambitious national targets for the development of both technology and market. However, the contribution that will be made by ocean energy technologies in providing a sustainable energy supply for rising future world needs remains unclear. The ability of the ocean energy sector to meet the following targets is questioned by scientists, politicians and industrial stakeholders: a. International sustainable energy targets b. Mitigating climate change by gradually replacing fossil fuel generation c. Providing affordable energy d. Creating new industries and jobs The OES-IA is currently the principal international body providing answers to these questions. A new work programme (Annex) covering the development of an international ocean energy roadmap has been proposed by the United Kingdom. Assuming a positive decision on this proposal, publishable results cannot be expected before the end of 2010. Consequently, a gap remains to be filled in the interim. This is the motivation behind the "International Vision for Ocean Energy".
Objectives	To provide a firm but interim vision for ocean energy by 2020 with a perspective on developments to 2050. To ensure ocean energy has a more integral role in the portfolio analysis of the IEA. The year 2020 has been chosen as it is expected that ocean energy technologies will be commercial by then. By 2050, ocean energy technologies are expected to be contributing fully to international energy portfolios.
Results	The proposed document will be a brochure type of about 16 to 20 pages with three key sections: i) Ocean Energy Resources, ii) Technologies and iii) Market development
Approach	The preparation of the document will be based upon a framework outlined by the project team, developed initially by the Chair and Vice-Chairs. The editorial team will lead the actual writing of the text with specific tasks assigned to internal (i.e. within the Executive) or external authors.
Led by	Editorial group from within the ExCo led by the Chair
Time frame	October 2009 – July 2010
Budget	40.000€ (for contracting external authors to study and write on specific issues and for the edition and publishing of the final document, including drafting of graphs and maps)

Full scale ocean test sites inventory	
Motivation	Over the past few years, several countries have taken specific measures to establish open sea testing infrastructures to enable development, demonstration & commercialisation of technologies as well as to address other regulatory and environmental issues. It is important to collate and share information from these new initiatives.
Objective	To obtain an international overview of open sea sites where wave or tidal energy technologies are being tested or planned, including an indication of the resources at the different sites.
Results	Map with localisation of each open sea test centre/pilot zone and database with respective detailed information available.
Approach	A questionnaire has been prepared and distributed to all members, being each member responsible for the collection of information in their own country. Afterwards those test centres will be contacted and a roundtable meeting exchanging information about each test centre/pilot zone is planned to be organised.
Led by	The project is led by the two Delegates Tony Lewis and Kim Nielsen
Time frame	June 2009 – December 2010
Budget	In-kind support

Database on Ocean Energy level of R&D,D investment and worldwide installed capacity	
Motivation	To establish an authoritative source of information on the international growth of ocean energy
Objective	To collect, compile and analyse data on: a. Level of R&D and Demonstration (public and private) Investment b. Worldwide Ocean Power Installed Capacity c. Electrical Utilities Involved in R&D and Demonstration
Results	Database with statistical information
Approach	Collection of data based on information provided by delegates by the end of the year
Compiled by	The ExCo Secretary
Time frame	To be updated once a year based on the feedback received from members.
Budget	Within the budget for secretariat services

2.4 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 inputs to several other IEA initiatives. These include:

- **Collaboration with the Renewable Energy Technology Development Implementing Agreement**
  Walt Musial, a specialist in wind energy and former US alternate to the OES-IA, was the OES-IA representative to the ExCo of the Renewable Energy Technology Development Implementing Agreement (RETD-IA) on its current project on Offshore Energy Deployment. During 2009, Mr. Musial has ceased to be US alternate to OES-IA and thus could not continue as representative to the RETD-IA project team. Mr. Hoyt Battey, from the US Department of Energy, Observer to the OES-IA ExCo meetings, became the OES-IA representative.

- **2009 edition of "*Energy Technologies at the Cutting Edge*"**
  The Chairman supplied information to an IEA survey on the ways in which industry participates in IA, for inclusion on a feature article on trends in industry participation in the 2009 edition of the IEA's "*Cutting Edge*" publication.

- **IEA Workshop on Renewable Energy and Water**
  IEA, Paris, France, 23 March 2009
  The REWP is the focus for the International Energy Agency's extensive international network for RD&D innovation and deployment in the area of renewable energy technologies. Delegates from IEA member countries convene each spring at the IEA Secretariat in Paris, along with leading international experts and policy makers, for the annual REWP technology and policy seminar on a theme considered pertinent to current developments in the renewable energy field. In 2009, the topic was "*Renewable Energy and Water*" and the REWP organised a workshop in the IEA offices in Paris on the 23rd of March 2009 with the aim of enhancing the exchange of information among experts and the IEA Implementing Agreements, thus contributing to deriving recommendations for both policy makers and industry, as well as highlighting priorities for the IEA collaborative programmes.

  The Chairman gave a presentation on the use of ocean energy for production of drinking water and desalination from ocean energy technologies, citing examples of pilot projects and technologies from India, Mexico and Australia.

- **55th Meeting of the IEA Working Party on Renewable Energy Technologies**
  IEA, Paris, France, 24-25 March 2009
  As previously noted, the OES-IA Chairman presented a mid-term report to the REWP on the ExCo's work to meet its current 5-year Strategic Plan.

- **Variable Renewables Project (GIVAR) IEA Workshop: Flexibility Assessment Method**
  IEA, Paris, France, 10 December 2009
  The Vice-Chair, José Villate, participated in the IEA workshop. The results of this workshop are confidential at present.

2.5 Participation in International Conferences

The OES-IA continued to strengthen its dissemination activities through presentations in events, conferences and symposiums, relevant to ocean energy.

3rd International Symposium on Marine Energy, co-sponsored by the OES-IA
Bilbao, Spain, 2 April 2009

This biennial conference was co-sponsored by the OES-IA and included a dedicated session, in which the OES-IA members shared their experiences with policies, incentives and subsidies to promote the demonstration and deployment of ocean energy technologies. Some members presented their experiences in assessing the technology challenges and lessons learned from early demonstration efforts in ocean energy projects. Further, the Chairman and Vice-Chairs gave keynote presentations on the following international events on behalf of the OES-IA:

1st International Ocean Energy Symposium
Harbin, China, 16-18 September 2009

The OES-IA Chairman had the honour to be a keynote speaker at the 1st International Ocean Energy Symposium, held at Harbin Engineering University. This well-attended and well-organized conference heard from both international speakers and local academics on the development of ocean energy. The range and depth of research into ocean energy in China was impressive, as were the wave and tidal testing tanks recently constructed at the University.

International Event	Local	Date
3rd International Symposium on Marine Energy	Bilbao, Spain	2 April 2009
2nd Annual Global Marine Renewable Energy Conference	Washington D.C., USA	15 – 16 April 2009
International Student Energy Summit (ISES)	Calgary, Alberta, Canada	11 – 13 June 2009
8th European Wave and Tidal Energy Conference	Uppsala, Sweden	8 – 10 September 2009
International Ocean Energy Symposium 2009	Harbin, China	16 – 18 September 2009
International Workshop – Future Marine Renewable Energies in Andalucía: Potential Opportunities	Cadiz, Spain	9 October 2009
37th College of Members of European Renewable Energy Research Centres (EUREC) Agency	Bilbao, Spain	3 December 2009

Organizers, Guests and Participants at the 1st International Ocean Energy Symposium, Harbin China

2.6 Organisation of Site Visits to the OES-IA Group

Mutriku Oscillating Water Column breakwater and bimep test site

This visit was organised by the Spanish alternate on the occasion of the 16th ExCo meeting in Bilbao. The members had the opportunity to visit the Oscillating Water Column (OWC) power plant integrated in Mutriku's breakwater promoted by EVE (The Basque Energy Board) and partially supported by the European Commission. Further, a visit to the test facility *bimep – Biscay Marine Energy Platform* was organised. This open sea testing site, which is an initiative from the Basque Government in Spain, will allow full-scale prototype testing and the installation of demonstration and pre-commercial wave power plants up to 20MW.

Mutriku OWC breakwater, Spain

Pilot project on osmotic power

This visit was organised by the Delegate from Norway during the 17th ExCo meeting in Oslo. The members visited Statkraft's first osmotic power plant in the world in Tofte, southwest of Oslo, which was built in the spring of 2008 and began operation in early 2009. Statkraft became involved in developing osmotic power in 1997. The main challenge is to develop a membrane which draws through enough water to create an effective pressure to run the turbine. Statkraft is working together with research and industrial groups in Norway, Germany and the Netherlands to improve the membrane technology.

2.7 Links with Other Organisations and Networks

The OES-IA has links with other international organisations and networks within the IEA and outside it:

International Electrotechnical Commission's Technical Committee 114

The OES-IA agreed to collaborate with the new established Technical Committee (TC) 114, *Marine Energy – Wave and Tidal Energy Converters*, to develop international standards for wave and tidal energy technologies that will help establish this promising source of renewable energy as a competitive form of electrical energy production. Several members of the OES-IA are also participating in this group. TC114 has 13 participating country members and 7 observer members. Thirteen of these 20 members are also members of OES-IA, so there is significant but not complete overlap between OES-IA and TC114 membership. Nonetheless, the similarity of memberships ensures that there is close communication between the two organizations.

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 under grant agreement n° FP721338. In May 2009, the Chairman was formally invited to be part of the EquiMar Project Steering Committee on behalf of the OES-IA. In October, the OES-IA Chairman and one of the OES-IA Vice-Chairs attended an EquiMar mid-term progress meeting in Brussels to act as external reviewers. A number of OES-IA ExCo representatives are directly involved in EquiMar project work.

Intergovernmental Panel on Climate Change Special Report on Rnenewable Energy Sources and Climate Change Mitigation

Five members of the Executive Committee were nominated by their governments and accepted by the Intergovernmental Panel on Climate Change (IPCC) to participate in the drafting of a Special Report on Renewable Energy Sources and Climate Change Mitigation. Four of the ExCo members are collaborating on the Ocean Energy chapter and one on the Geothermal Energy chapter. The Special Report is a wide-ranging review of all renewable energy resources and technologies; it also includes reviews of their potential to mitigate climate change. The First Order Draft of the Special Report was completed in mid-December for review by external experts. Two further drafts are planned for 2010 to be presented with the final version of the report, being completed in late 2010 – early 2011.

3. Task Status Report

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

Operating Agent:
Dr. Teresa Pontes (Portuguese Delegate)
Laboratório Nacional de Energia e Geologia, I.P. (LNEG), Portugal

Objectives

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. This available knowledge should facilitate further development and adoption of cost-effective ocean energy systems. In addition, the results of this task will facilitate identification of further Annexes, as well as continuing to promote information exchange.

Achievements and Progress in 2009

Distribution of the Information DVD on Ocean Energy

The DVD on Ocean Energy produced in 2008 was distributed in 2009 to the OES-IA member-countries as well as to governments, institutions and companies with interest on Ocean Energy as a means to educate decision-makers, financiers, technical people and the general public on how ocean energy can contribute to a sustainable energy future. This DVD is available on the OES-IA website.

Newsletter

The 12th issue of the OES-IA Newsletter includes articles with contributions from the member-countries on ocean energy initiatives in addition to the listing of events occurred in 2009 and planned for the new future. The 12th Issue was focussed on new Ocean Energy test centres as follows:

- Runde Environmental Centre, Norway
- SEM-REV – Full-scale wave energy test centre, France
- Wave Energy Pilot Zone, Portugal

OES-IA On-line Reference Library

This on-line library continued to be populated with references from conferences held in 2009. The references are organized into 18 main topics. The references can be sorted out by chronological order, alphabetical order of titles, authors and types. From this Library the UK Supergen Library can be can be directly accessed. It is planned to include soon access to National Reports that are of general interest.

Publications

Two new publications prepared in 2007-2008 were launched in early 2009:

- T. Pontes and A. Candelária (2009). Wave Data Catalogue for Resource Assessment of OES-IA Member Countries, Report from INETI for the OES-IA.
- J. Khan and G. Bhuyan (2009). Ocean Energy: Global Technology Development Status, Report prepared by Powertech Labs for the OES-IA. [Online], Available: www.iea-oceans.org

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

Operating Agent:
Dr Kim Nielsen (Danish alternate)
RAMBØLL, Denmark

Objectives

The objective of Annex II is to recommend procedures for development, testing and evaluating ocean energy systems. The extended work programme is intended to provide the necessary basis to present the performance of different wave and tidal energy prototypes in a comparable format, even if they are tested at sea at different locations and are at different development stages.

Achievements and Progress in 2009

The new Annex II reports available on the OES-IA website are:

Task 1 Generic and Specific Wave and Tidal Current Reference Data
Report T02-1.1: *Generic and Site-Specific Wave Resource Data,* by INETI/LNEG and Ramboll (in progress)
Report T02-1.2: *Guidance for Assessing Tidal Current Energy Resources*, by A. Cornett, (2008) NRC-CHC
Task 2 Development and Evaluation Protocols for Ocean Energy
Report T02-2.1: *Development and Evaluation Protocols for Wave Energy,* by HMRC (in progress)
Report T02-2.2: *Tidal Development Protocol*, by A. S. Bahaj, L. Blunden and A. A. Anwar, (2008) University of Southampton
Task 3 Guidelines for Open Sea Testing and Evaluation of Ocean Energy Systems
Report T02-3.1: *Preliminary Wave Energy Device Performance Protocol,* by G. Smith Heriot-Watt University and J. Taylor, Edinburgh University (2007)
Report T02-3.2: *Preliminary Tidal Current Energy: Device Performance Protocol*, by S. J. Couch and H. Jeffrey, Edinburgh University (2007)
Report T02-3.3: *Guidelines for the Design Basis of Marine Energy Converters*, by Peter Davies, Lloyd's Register EMEA,(2009), European Marine Energy Centre Ltd

Workshop OES-IA, Annex II, Marine Resources & Device Testing
4 November 2009, Lisbon

In November 2009, part of the work carried out under Annex II, specifically tasks 1.1, 1.2, 2.1 and 2.2, was presented by Teresa Pontes (INETI/LNEG) at a two-hour workshop in Portugal in connection with an international conference on ocean energy that was held in Lisbon. The workshop was attended by 20 participants, mainly from the industry sector. The workshop was an opportunity to discuss and exchange experience on the aspects included in the Annex II of the OES-IA with the participants, concerning resource data and guidelines on development steps for open sea testing of both wave and tidal energy systems.

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

Operating Agent:
Dr. Gouri S. Bhuyan
Powertech Labs Inc. (a Clean Energy Technology Subsidiary of BC Hydro), Canada

Background and 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 following three 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 initial scope of this Work Package included compilation of existing and new case studies, illustrating distribution and/or transmission network modelling, involving integration of wave and tidal current power plants. A revised scope of this Work Package is detailed later.

The work programme also included "Coordination" activities with other relevant IEA initiatives, and the Operating Agent has currently been coordinating the activities of this Annex with other activities.

Participating Countries and Organisations

The ExCo member countries that are participating in the work programme of the Annex are Canada, Ireland, United Kingdom, Spain and New Zealand. Powertech Labs of Canada is the leader for the WP 1, with contribution from the Department of Energy & Climate Change (DECC), UK (through AEA Technology), Sustainable Energy Ireland (SEI), Ireland (through the Hydraulic Maritime Research Centre – HMRC), TECNALIA, Spain, Aotearoa Wave and Tidal Energy Association (AWATEA), New Zealand, and others. HMRC of Ireland is the leader for the WP 2. Potential contributions to this WP are expected from Canada, Spain and others. TECNALIA and Powertech have been confirmed as the co-leaders for the WP 3. Potential contributions to this WP are expected from Spain, Ireland, Canada and others.

Achievements and Progress in 2009

Work Package 1, led by Powertech Labs, was completed, and the following two reports, (1) IEA-OES Doc. T0311 and (2) IEA-OES Doc. T0312, were published:

- IEA-OES Doc. T03011 on "*Potential opportunities and differences associated with integration of ocean wave and marine current energy plants, in comparison to wind energy*". This document presents characteristics of some wave and tidal current energy conversion processes and identifies areas where the ocean energy technologies bear unique advantages in comparison to wind energy technologies. The report also discusses how the experience gained from the wind energy industry could be used to mitigate any future grid integration challenges associated with a large-scale implementation of ocean energy technologies.

- IEA-OES Doc. T0312 on "*Key features and identification of improvement needs to the existing relevant interconnection guidelines for facilitating integration of ocean energy pilot projects*". This report presents a review of some relevant interconnection guidelines and identifies key components of a generic guideline. Considering the early deployment stage of ocean energy technologies, the report discusses how a flexible interconnection guideline could be developed to accelerate the deployment.

The activity of Work Package 2, initiated by HMRC during the early part of the year, made significant progress during the year. The following specific activities of the WP were completed:

- Assessing grid companies requirements
- Comparing with more mature generation technology and equivalent scale, e.g. wind, small scale hydro
- Defining generic model structure based on a comprehensive device review
- Producing requirements specification for model (inputs/outputs, time series, etc)
- Developing an Ocean Energy Devices Developer Questionnaire

A progress meeting was held in Uppsala, in September 2009, to discuss the WP2 activities and to revise the scope and plan of action for the WP3 activities. After the progress meeting, a revised scope of the WP3 was approved by the participants in the Annex.

The Executive Committee of the OES-IA approved an extension of the Annex till the end of 2010.

Plan for 2010

By the end of March 2010, the activities for WP2 will be completed and an Annex Report including a compiled comprehensive database on characteristics of ocean energy generators for wave and tidal systems will be prepared for approval of the Executive Committee.

The activities of WP3 will be initiated in January. Based on the completion of activities through this Work Package, an Annex Report, consisting of the following parts, will be prepared by the end of 2010:

- ***Part 1:*** This will be an introductory section discussing variability of wave and tidal current resources, as well as generation characteristics, of some wave and tidal current conversion processes. Then, this section will present meaning of grid integration, define various relevant terms and discuss relevant grid integration issues, such as power quality, active and reactive power, capacity limits, etc. The section will also briefly discuss different grid codes.

- ***Part 2*:** This section will present how potential grid integration issues can be managed, considering various factors, including factors like site, characteristics of conversion systems, layout of devices, and system control.

- ***Part 3a:*** This sub-section will present case studies illustrating integration of wave energy plants to distribution grid (only non-proprietary information will be presented).

- ***Part 3b*:** This sub-section will present a case study illustrating integration of aggregate wave energy plants to a larger power system at transmission levels (only non-proprietary information will be presented), considering various long-term (2020) system scenarios (only non-proprietary information will be presented).

- ***Part 4:*** This section will be the conclusive part of the WP report that will include recommendation for future relevant work items, based on the knowledge gained through the Annex III work, for consideration of the OES-IA Executive Committee.

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

Operating Agent:
Mr. 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 to:

1) expand baseline knowledge of environment effects and, particularly, environmental monitoring methods,
2) ensure that this information is widely accessible,
3) make available any proven mitigation strategies, and
4) 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 select 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 2009

After this Annex was approved by the IEA-OES Executive Committee in the end of 2008, all interested parties held an initial web meeting in February of 2009 and formalized commitments between then and March of 2009, when the Executive Committee met in Bilbao, Spain. There are currently seven participating countries, including Canada, Ireland, Spain, Sweden, Norway, New Zealand, and the United States.

In July 2009, the member countries held another web meeting to discuss and finalize the proposed work plan and budget for the project. After the September meeting of the Executive Committee in Oslo, Norway, members have been developing the statement of work for a consultant to carry out many of the project's logistical activities and to aid in data gathering and analysis. The goal for the final weeks of 2009 is for member countries to finalize the statement of work for the consultant, so that a competitive solicitation can be released in the beginning of 2010.

4. Invited Articles on Ocean Energy

In 2008, the OES-IA Executive Committee (ExCo) invited, for the first time, papers from industry experts on specific themes relevant to ocean energy. In the 2008 Annual Report, five industry experts presented review papers on specific ocean energy technologies, including wave, tidal range, tidal current, ocean thermal energy conversion and salinity gradient technologies. A further paper covered utilization of ocean energy for producing drinking water.

These summary papers were well-received, so the ExCo sought papers from industry experts with a theme on technical and non-technical barriers to uptake and acceleration of ocean energy technologies and mitigation of these barriers. The five papers presented in this chapter cover a range of barriers and issues, ranging from staged development processes for ocean energy technologies to regulatory issues in global jurisdictions.

The Opportunity and Challenge for Ocean Energy as Part of Energy System Decarbonisation: the UK Scenario
Dr. Henry Jeffrey and Dr. Mark Winskel
UK Energy Research Centre (UKERC), Edinburgh University, United Kingdom

Marine Energy Device Development: A Structured Programme to Mitigate Technical & Financial Risk
Mr. Brian Holmes
Hydraulic Maritime Research Centre (HMRC), University College Cork, Ireland

Ocean Energy as Ocean Space Use – Only Conflicts or Also Synergies?
Mr. Frank Neumann
Wave Energy Centre, Portugal

Overview of Global Regulatory Processes for Permits, Consents and Authorization of Marine Renewables
Ms. Carolyn Elefant
Law Offices of Carolyn Elefant, Ocean Renewable Energy Coalition (OREC), USA

The Standardization of Marine Renewable Energy Conversion Systems
Ms. Melanie Nadeau
CanmetENERGY, Natural Resources Canada, Ontario, Canada

The Opportunity and Challenge for Ocean Energy as Part of Energy System Decarbonisation: the UK Scenario

Henry Jeffrey, Mark Winskel
UK Energy Research Centre (UKERC), Edinburgh University, United Kingdom

The Challenge of Decarbonisation

This is a time of unprecedented attention on energy systems, certainly since the energy crisis of the 1970s. The broad acceptance that carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions are responsible for climate change has made decarbonisation of the economy an international policy priority (IPCC, 2007). Ambitious targets for economy-wide decarbonisation and low carbon technology deployment are being established across international policy, industry and research communities.

As part of this, the UK has set out a legally binding framework for decarbonisation from now to 2050. Following a recommendation by the UK Committee on Climate Change, the UK's reduction target for all greenhouse gases (GHGs) is at least 80% below 1990 levels by 2050, with a recommended interim target of at least 34% by 2020 (CCC, 2008).[1] These targets – some of the most ambitious legally binding levels of GHG reductions anywhere in the world – have been incorporated in the UK Climate Change Act (UK Government, 2008a). Ocean energy is one of a number of emerging low carbon supply options that has the potential to help meet these targets.

Alongside major deployments of more mature low carbon supply technologies over the next decade, there is an opportunity for currently less mature emerging technologies, such as ocean energy, to contribute significantly to deeper decarbonisation over the medium to long term. Realising this potential will involve a complex interplay between technology *development* (and learning-by-research) and technology *deployment* (and learning-by-experience).

This paper begins by highlighting the specific technical challenges associated with the development of ocean energy. It will then use the UK as a case study to illustrate and discuss the potential deployment that could be achieved if these challenges are overcome and ocean energy competes in the overall energy mix. Building on the results from this case study the paper will culminate by laying out and summarizing the high level challenges associated with the large scale international deployment of ocean energy.

Ocean Energy

Ocean energy (defined here as wave and tidal current technology[2]) is an emerging technology field with considerable promise. For example, it has been estimated that around 15-20% of UK electricity demand could be met by ocean energy (Carbon Trust, 2006). This said, ocean energy innovation and industrial systems are at a relatively early stage of development as compared, for example, to wind power, and this is reflected in a wide variety of prototype device designs.

For example, there is still a wide range of engineering concepts for capturing wave energy, including oscillating water columns, overtopping devices, point absorbers, terminators, attenuators and flexible structures. Tidal current energy exhibits less variety, with most prototype designs based on horizontal axis turbines, but vertical-axis rotors, reciprocating hydrofoils and Venturi-effect devices are also being developed. Two UK based companies (Pelamis Wave Power and Marine Current Turbines) have recently installed full-scale devices that are representative of the sectors' progress, Figure 1.

In the wake of the 1970s energy crisis, a number of wave energy Research & Development (R&D) programmes were established internationally, but – in contrast with wind energy – these efforts were not sustained, and there was very limited innovation in the ocean energy sector from the mid-1980s to late 1990s. Renewed policy interest (and public and private funding) over the last decade has provoked a resurgence in innovation activity, and the emergence of multiple device designs. These more recent efforts have been

[1] The UK Climate Change Committee recommended that the decarbonisation targets be applied to all greenhouse gases, and not just CO_2 emissions This was subsequently accepted in the UK Climate Change Act (CCC, 2008; UK Government, 2008). Non– CO_2 emissions accounted for 15% of total GHG emissions in 2006 (CCC, 2008). The modelling scenarios presented in this report only consider CO_2 emissions.

[2] Tidal barrages, lagoons or ocean thermal circulation technologies are not addressed here.

Figure 1: Full Scale Marine Energy Devices: Pelamis Wave Power (left) and Marine Current Turbines Seagen Device (right); (Sources: PWP, MCT)

led initially by small and medium enterprises (SMEs) and university consortia, although large power companies and large scale public-private programmes are increasingly involved.
International interest and development activity has grown rapidly in recent years, and over a dozen countries now have specific support policies for the ocean energy sector. Additionally, full scale ocean energy test centres have been established in the UK and continental Europe, with new centres being built in the United States and Canada. Additionally, this international interest and growth has lead to the development of international standards specifically for ocean energy.

The nascent status of ocean energy technology creates considerable challenges for its development. In particular, there is a need to strike a balance between trials of the most advanced prototype devices, and also research on more radical but less developed designs and components. The Carbon Trust have indicated long term learning rates for wave and tidal energy of up to 15% and 10% respectively, but also highlighted the importance of taking advantage of step change improvements (Carbon Trust, 2006).

Research Challenges and Priorities

As indicated in the previous section, both wave and tidal current energy still face a number of significant technology challenges in order to reach fully commercial status. A representative, but by no means exhaustive, summary of the general challenges for the sector is provided below:

- At present ocean energy innovation activity is spread over a wide variety of concepts and components, and at the highest level, wave and tidal current have distinctive innovation needs. Although this variety of device design and experimentation is important, it may create problems in terms focussing R&D investment and the speed of commercialisation. Across the sector as a whole, there is a need to strike a balance between prototype design variety and consensus, and to manage the selection processes for linking between the two. While resources and effort tend to focus on a few large-scale wave and tidal current prototypes (up to around 1MW), and more conventional designs and components, there is a parallel need to explore more radical options which may offer step-change cost reductions or performance improvements. This can be understood as a balance between early-stage learning-by-research and later-stage learning-by-doing.

- At the same time, a number of generic technologies and components – such as foundations, moorings, marine operations and resource assessment – offer opportunities for collaborative learning, although the transfer of generic knowledge and components within the developer community is limited by commercial competition (Winskel, 2007).

- Given limited full scale experience in real operating conditions, there is a need for more data on prototype performance and operating experience to feed back into the overall Research, Development & Demonstration (RD&D) cycle.

- There are significant opportunities for knowledge transfer from other sectors, such as offshore engineering. Enabling this transfer will involve better understanding of the 'adaption costs' of transferring components and methods to the marine environment, and identifying opportunities for collaboration with other industries and supply chain partners.

Case Study: Potential Development and Deployment of Ocean Energy in the UK

This case study investigates the prospects for accelerated development of a range of ocean energy supply technologies, and the impact of this acceleration on the decarbonisation of the UK energy system. Technology acceleration is analysed firstly by devising detailed single technology scenario (ocean energy) of accelerated development, and then system-level modelling of the potential impacts of this acceleration on the UK energy system from now to 2050. The results of the case study highlight the potentially important role for ocean energy technology acceleration in the transition to a low carbon energy system in the UK, and also its wider international significance.

Input Assumptions

Given the leading position of the UK in the ocean energy sector, domestic innovation support policies are potentially able to influence the progression of the sector internationally over the short to medium term. Using plausible deployment figures for the period to 2015, and international learning rates and initial capital cost figures derived from the Carbon Trust (Carbon Trust, 2006), 'accelerated' learning curves for wave and tidal were produced. (Note that this analysis is based on the continuation and expansion of tariff and capital support mechanisms in the UK and elsewhere to support niche deployment and learning).

Results: Single Technology Scenario

In the single technology scenario (Figure 2 above), with ocean energy technologies accelerated alone (and all other technologies under non-accelerated 'business as usual' assumptions), technology acceleration makes a substantial difference to the deployment of ocean energy technology in the UK, with over 20GW of installed capacity by 2050.

Results: Aggregated Scenario

In the aggregated scenario case, all low carbon energy supply technologies are accelerated in parallel and compete for market share. In this case ocean energy continues to make a significant contribution to the supply mix (see Figure 3, here ocean energy supplies almost 15% of all electricity generated in 2050, i.e. over 240PJ (67 TWh)).

Discussion of Results

These scenarios provide only possible illustrations of the future. In practice the feasibility of their implementation depends on many issues beyond the relative costs and performance of different supply technologies, such as raw material prices, supply chain capacities and investment risks. In addition, energy system change is also affected by patterns of energy demand, the networks used to transfer energy between production and consumption, and many other regulatory, organisational and political interests and pressures.

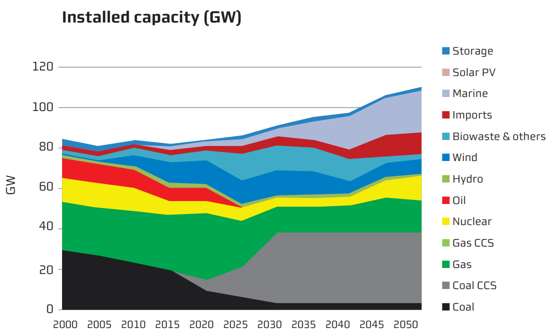

Figure 2: Indicated impact of ocean energy acceleration in the UK (2000-2050)

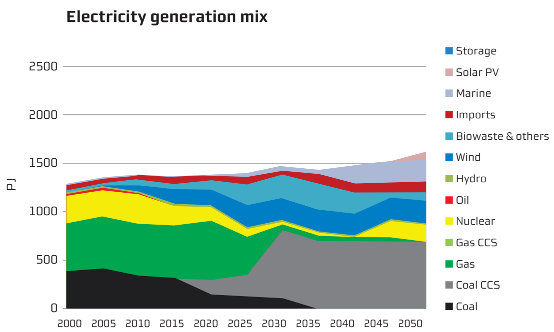

Figure 3: Indicated impact ocean energy in a UK aggregated scenario

For this scenario to be realised, over the period to 2020 there is likely to be a progressive device design consensus, with a distinct group of wave and tidal designs becoming 'industry standards'. Consolidation in the marketplace is also likely, with mergers and acquisitions allowing hybrids of the best technologies to emerge and reduce overall costs. Up to and beyond 2020, it is conceivable that disruptive technologies, embodying novel approaches to energy extraction, will be introduced, allowing for accelerated cost reduction, although the timing of these breakthroughs is difficult to predict. UKERC's Marine Energy Technology Roadmap (UKERC, 2008a) details the technology and commercial challenges involved in establishing a deployment strategy for the ocean energy sector up to 2020.

Beyond 2030, it is implausible to speculate in any detail as to the future direction of the industry; however, given continued publicly and privately funded development programmes, and associated learning effects, device costs are likely to decrease, and performance increase. While an accelerated development trajectory for the ocean energy sector involves some degree of design consensus over the medium term, there is a danger that if this consensus is imposed too early it may lead to 'lock-in' around devices with less scope for development in the longer term.

Summary of International Challenges

Realising ocean energy development scenarios will depend on a co-evolution of accelerated *development* and *deployment*, with ocean energy technologies benefiting from learning-by-experience associated with early deployments, in conjunction with learning-by-research to enable step changes in technology performance and cost.

The significant levels of deployment indicated in the case study scenarios, when replicated internationally, are unlikely to be met with the existing international supply chain infrastructure, and will require considerable investment in specialised and dedicated installation equipment. Some of this investment is already underway: for example, some technology developers have already taken delivery of dedicated installation vessels. Additionally, technology acceleration will involve measures to address the generic technical challenges highlighted in the UKERC Marine Technology Roadmap (Figure 4, below)

Figure 4: Generic Technical Challenges involved in Marine Energy Technology Acceleration

A coherent and adaptive approach to policy, across international energy arenas, will be needed to provide an appropriate combination of support mechanisms, and ensure effective distribution of investments as the sector matures.

Overall, in the short term, there will be considerable deployment challenges for the sector, with planning and legislation, human resource skills shortages, and availability of installation vessels all being significant hurdles. Despite a certain level of existing headroom, grid reinforcement will also be a significant challenge for many countries during this period.

In the medium term the challenges of planning and regulation should have been largely addressed. Despite the capacity that will have been built up in the preceding period, skills shortages and availability of vessels will still be a challenge to the sector due to the ramp-up in build rate in this period. Given the remote nature of many of the ocean energy resources, major grid reinforcements will be a major challenge during this period, with the need for an offshore grid highly likely. International initiatives, such as the "European Supergrid", are already beginning to address this issue.

The long term appears less challenging for the sector, to the extent that many earlier limitations need to have already been managed (such as supply chain constraints, planning constraints and grid implications). However, additional capacity may be exploitable by this time, so that deployment may continue increasing beyond, for example that indicated in the UK case study, above. In addition, competition for resources from other energy and non-energy sectors could have significant impacts on their availability to the ocean energy sector across all time periods.

Conclusion

Ocean energy is an emerging technology field with considerable promise over the medium and longer term. The industry has just started demonstrating full-scale devices and device arrays. The nascent status of ocean energy technology creates considerable scope for accelerated development. In realising this potential, however, there is a need to allow for parallel progress in demonstration trials of the most advanced wave and tidal prototype devices, and also research on more radical but less developed designs and components.

The case study scenario described here indicates that technology acceleration has the potential to make a substantial difference to the deployment of ocean energy technology in the UK, with initial deployments starting soon after 2010, and rapid expansion after 2030. Under these accelerated development assumptions, ocean energy supplies almost 15% of all electricity generated by 2050, and additional exploitable resource may allow for further increases to this figure.

Accelerating ocean energy to achieve these deployment levels will require sustained support for its development over time. A coherent and adaptive approach to policy, in the UK and internationally, will be needed to ensure effective investments as the sector matures. In particular, there is a need to strike an effective balance between technology-push and market-pull mechanisms, to allow for design consensus, but at the same time avoiding 'lock-out' of breakthrough technologies which may allow for step-change improvements. There are also considerable associated investment needs in supply chains, installation capacity, and electricity networks. With these in place, the work here indicates that ocean energy can become a significant contributor to low carbon energy supply systems in the UK and beyond.

Acknowledgements

The research for this paper and case study was conducted under the auspices of the UK Energy Research Centre (UKERC) which is funded by the Natural Environment Research Council, the Engineering and Physical Sciences Research Council and the Economic and Social Research Council.

More specifically, the research reported here has been supported by energy systems analysis using the UK MARKAL elastic demand (MED) model. The operation of the UK MARKAL MED model is detailed in the report (Anandarajah et al., 2008).

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Marine Energy Device Development: A Structured Programme to Mitigate Technical & Financial Risk

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Note: The phased development schedule & test programmes described in this article are appropriate to both wave and tidal devices. However, the details will be specific to the different technologies so for clarity only the application to wave energy is covered. A full description for tidal device progression is under review for inclusion in the OES-IA Annex II.[1]

1. Introduction

Volatile primary fuel prices, climate change, diminishing raw fossil fuel stocks and security of supply are some of the reasons National governments and international organisations are looking seriously at alternative energy source for electricity generation. This article describes a systematic approach to developing one of those renewable, sustainable options, wave energy.

A great deal has already been learned about the requirements for extracting energy from ocean waves, both at a fundamental physics level and the heavy marine engineering necessary for safe operation at sea. However, at the current stage of technical advancement the development of ocean energy devices must, inevitable, be a careful, patient and reasonably expensive process. As the knowledge base expands from further experiences and understanding the required rigorous approach may be relaxed but for now a cautious and measured methodology should be followed if the reward of economically harvesting the vast amounts of energy contained in the world's oceans and seas is to be achieved in an accelerating time frame.

Persuading technology developers to follow a controlled and careful approach is becoming even more important at the present time since there seems to be an urgency setting in, manifesting as a rush to launch devices in the sea regardless of their Technology Readiness Level (TRL)[2]. Although marine energy can only become a reality following full scale testing of wave energy converters (WEC) at sea it is important that the correct engineering procedures are followed leading up to the first sea trials. Although difficult, political and business concerns must resist applying pressure to deploy new devices prematurely.

However, a cautious approach should not be regarded as a slow advance, indeed evidence shows that by following a structured programme device development is quicker since the unexpected problems some meteoric rising companies are encountering can be avoided. Most of the current leading pioneers of wave energy devices have been astute and followed a development schedule of some description, which is one reason they are the most advanced. Figure 1 shows the development profiles of some devices. If early tests were rushed the device can become delayed in later stages. This is because the ocean is not a place to investigate options but rather somewhere to verify designs proven in a more controlled environment.

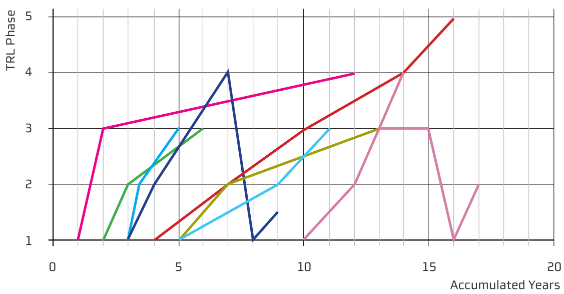

Figure 1: WEC Development Profiles

The systematic programme presented here is now becoming accepted as the best practice and it is being formalised in a document under production by the Annex II of the Ocean Energy Systems Implementing Agreement. The purpose of the programme is to reduce the technical and financial risks encountered during the development process by investigating engineering elements at the appropriate time and cost.

It should be stated, however, that even following an organised and well planned test programme is no guarantee of success but not following one is probably a pathway to disappointment, lost time and wasted resources.

[1] http://www.berr.gov.uk/files/file48401.pdf

[2] http://en.wikipedia.org/wiki/Technology_readiness_level

2. Chronology

Even though wave energy research began seriously following the oil crisis of the late 1970s no formalised guidelines, recommended procedures, or best practice manuals that developers could reference and follow appeared until 2003. Until that time the vanguard companies had to design their own development schedules and test programmes on an ad hoc basis, and usually in isolation from each other.

Most of the initial investigation took place in the UK but in the early 1990s the European Union [formerly the European Economic Community] became interested in the potential of ocean power supplying electricity into the member states energy portfolios. One of the first proposals supported was the Offshore Wave Energy Converter Project (OWEC1)[3]. A section of the review sketched out a test programme which was documented in 1995. However, nothing was advanced on this report and the schedule did not become a standard approach to be applied throughout the member states researching the area.

The OWEC1 development schedule was used as the framework for the ***Irish Wave Energy Development & Evaluation Protocol*** published and implemented in 2003[4] and the Danish wave energy programme, 1998-2002.[5] Since the development schedules were supported by both countries funding agencies, wave energy converter (WEC) companies soon followed the recommended phased approach based on a Technology Readiness Level method. Perhaps not totally supportive at the time these companies would now be key endorsers of the staged approach.

2.1 Increased Awareness

Since the turn of the Millennium many other influential and authoritative groups have become interested in establishing a series of standard, equitable approaches for both the development schedule and the test programmes that should be adopted during the progress of wave energy devices from concept to demonstration. The list below includes the main bodies pursuing this objective.

- the International Electrotechnical Commission's Technical Committee 114 (IEC TC114)
- the Ocean Energy Systems Implementing Agreement (OES-IA)
- the UK Department of Climate Change (DECC), via European Marine Energy Centre (EMEC)
- Sustainable Energy Ireland (SEI), via Ocean Energy Development Unit (OEDU)
- the UK Carbon Trust via Det Norske Veritas (DNV)
- the International Standards Organization & British Standards Institute (ISO & BSI)
- the UK Engineering & Physics Research Council (EPSRC) via SuperGen Marine Consortium
- the European Union, via Seventh Framework Programme (FP7) project EquiMar (Equitable Testing and Evaluation of Marine Energy Extraction Devices)
- the US Department of Energy (DOE) via National Renewable Energy Laboratory (NREL)

It has, therefore, become important not only to establish agreed and accepted procedures but also to synchronise the different group's documentation. Ideally this will lead to a complimentary and co-ordinated programme and certainly ensure they are not contradictory.

3. The Technology Readiness Level Schedule

Technology Readiness Level (TRL) development programmes are standard approaches for product advancement in established industries. They are particularly important in American military equipment design and were the cornerstone in NASA's very successful moon landing programme[6]. More important perhaps than the overall budget!

The principle of such a schedule is to sequence the design development so the required knowledge is obtained at different stages to enable the safe transmission along a path of increasing technical complexity and investment requirements. In the case of ocean energy device development the stages can be linked to different model scales by following Froude Similitude Laws and geometric similarity rules[7].

These accepted and proven modelling laws correctly scale the various important physical properties such

[3] The Offshore Wave Energy Converter Project-1, Danish Wave Power APS, 1996 (EU JOULE contract no. JOU2-CT93-0394)

[4] http://www.sei.ie/Renewables/Ocean_Energy/OceanEnergyIndustryForum/Forum_Archive/Development_and_Evaluation_Protocol.pdf

[5] The Danish Wave Energy Programme, Nielsen K, Meyer N, Proc of the 3rd European Wave Energy Conference, 1998

[6] http://history.nasa.gov/apollo.html, http://en.wikipedia.org/wiki/Apollo_program

[7] Physical Models & Laboratory Techniques in Coastal Engineering; Hughes S., World Scientific Publishing, 1993

that results at one size can be confidentially extrapolated to larger and full prototype scales. This in turn means important information and design criteria can be investigated at appropriate stages of development to optimise the time and costs involved in the evolution of taking a design from concept to market. However, as with all engineering solutions there are practical considerations. Not all physical processes scale as precisely as it would be convenient, and some components can not be physically modelled, which leads to the proposed staged programme, designed to enable all factors to be studied at the correct time.

To accommodate all requirements a 5-stage TRL schedule has evolved as the optimum for the development of ocean energy extraction devices. Figure 2 shows the overall structure of the programme. Although presented as a linear path device development should not be regarded as a straight line process. Feedback loops and repetition of stages should not be unexpected. The 5 stages basically align with small (1:50 – 100), medium (1:10 – 25), large (1:3 – 8) and full (1:1 – 2) scale models that can be tested initially in hydraulic laboratories and, at later stages, in the open ocean.

The test programme applied at each TRL is very important but, of equal merit, is the stage gate decision procedure that should be implemented at the end of each test programme. In many ways these essential due diligence processes are the most difficult parts of the schedule to establish, and achieving agreement on the recommended evaluation criteria is not a trivial task.

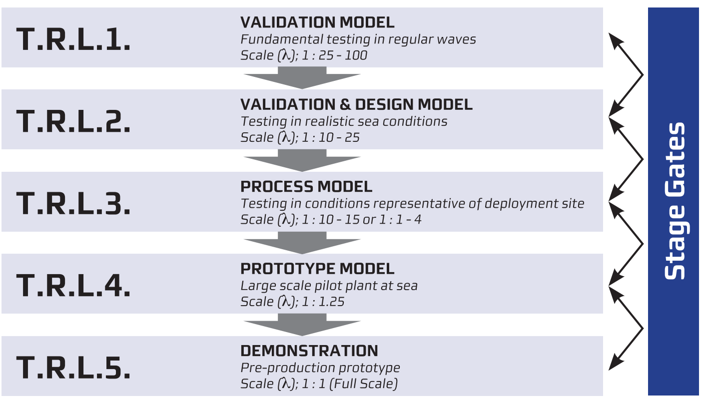

Figure 2: WEC TRL Development Programme

3.1 Stage Gates

At present it is often left to individual marine energy device developers to set their own design acceptance parameters since no consensus on robust, generic or standard evaluation procedures has been established. This has lead to the situation where the only measure often applied is the extrapolated estimated cost per kilowatt (c/kW) of electricity generated. Obviously, this value is an important criteria but it is difficult to apply with any confidence in the early stages of development, though essential in the later TRLs.

Other factors such as the size, weight, manufacturing, deployment and operational complexity, power take-off (PTO) survival, hull seaworthiness and station keeping matters can also be considered. The numbers can be summarised into evaluation parameters such as electrical production per dwt ( ) (kW/tonne) or per displaced volume (∇) (kW/m^3). [These project continuation criteria are currently under review by several of the bodies listed in Section 2].

As stated above using alternative, robust benchmarks to compare devices, or even assess a single unit against threshold values, is not a simple, or clear, undertaking but such a system is necessary if funds and time are to be focused on the devices offering the greatest potential of large scale deployment. This evaluation is particularly relevant to ocean energy, and in particular wave power, since the possibility of extracting the resource seems to have captured the imagination of inventors and engineers as much as the early days of flight did at the turn of the last century. At present, over 100 designs are being investigated at the various TRLs.

4. Test Programmes

The actual test programme required for each WEC is, inevitably, a bespoke plan appropriate for each TRL stage. However, the overall approaches for each of the 5 stages are generic as described below. It should be noted that an important element of the stage development is that conditions are controllable and repeatable in hydraulic facilities for TRL1 & 2 but only acceptable as they occur for TRLs above this. Programmes have to be structured to accommodate this loss of control. The boundaries between TRLs are not sharp and can often merge but this should not lead to missing a stage completely.

4.1 Technology Readiness Level 1 [addressing the Unknown – Unknowns]

The primary purpose of TRL1 is to prove the basic concept of the proposed WEC in regular waves and obtain an estimate of its power performance in irregular, real sea waves.

At the beginning of the process most devices have many design variables that can influence the behaviour and performance under wave excitation. For this reason the stage is divided into 3 sections of small (scale = 1:25 – 100) scale testing as summarised in Table 4.1. Budget and durations estimates for TRL1 are also indicated. A typical idealised physical model is shown in Figure 4.1.

Once the design variables have been individually investigated in regular wave to optimise the machine, it is tested in irregular seas to evaluate the performance potential. To conduct this process fully a specified number of sea states are run extending from calm to storm conditions but focussing on the design seaways.

A typical selection of design criteria to be investigated in all sections of the TRL is shown below.

Validation Model: Phase 1 — Scale: 1:25-100

SECTION	TIMETABLE (Including Analysis)	Budget (€000)
Idea	1 – 5 Days	1-5
Concept	1 – 3 Months	25-75
Performance	1 – 3 Months	
Optimisation	1 – 3 Months	25-50

Table 4.1: TRL 1 Format – schedule & budget

Figure 4.1: Idealised TRL 1 Model [courtesy Oceanlinx Ltd]

TRL1 – Pre-design stage gate requirements

- Linear monochromatic waves to validate or calibrate numerical models of the system (25 – 100 waves).
- Finite monochromatic waves to include higher order effects (25 – 100 waves)
- Hull(s) sea worthiness in real seas (scaled duration at 3 hours).
- Restricted degrees of freedom (DoF) if required by the early mathematical models.
- Provide the empirical hydrodynamic coefficient associated with the device (also mathematical modelling).
- Investigate physical process governing device response. May not be well defined theoretically or numerically solvable.
- Real seaway productivity (scaled duration at 20-30 minutes)
- Initially 2-D (flume) test programme
- Short crested seas need only be run at this early stage if the devices anticipated performance would be significantly affected by them.

4.2 Technology Readiness Level 2 [addressing the Known – Unknowns]

If the WEC satisfies the stage gate criteria applied at the conclusion of TRL1, a larger model (circa 1:10) is constructed. There should now be fewer design options to investigate but rather TRL2 concentrates on specific component testing in more seaways, including those expected at future external sea trial sites.

Since the TRL3 requires a fully functional large scale device deployed in open water a complete engineering study should be undertaken in this TRL2. Table 4.2 shows the expected budget and duration breakdown for this phase and a typical model in Figure 4.2.

Of particular importance is the evaluation of control strategies to be applied on the power take-off system. Models should be physically large enough to incorporate the equipment and sensors required to conduct these tests.

The anticipated mooring arrangement should be deployed so the corresponding forces can be monitored to verify the design prior to later sea trials. Failure modes should be included.

Besides producing accurate results that will reduce the error band applied in the stage gate criteria, the rationale for TRL2 is to verify all the data generated in TRL1. This validation is required to justify the design decisions transferred between the TRLs.

A list of some of some of the factors to include in TRL2 is shown below.

Design Model: Phase 2		Scale: 1:10-25
SECTION	**TIMETABLE**	**Budget (€000)**
Performance	1 – 3 Months	25-50
Survival	1 Month	15-25
Mathematical Model		10-20
Hull Design		15-25
Power Take –Off		25-75
Control		
Generator & Power Elecs		25-50
Mooring & Anchor		15-25
Preliminary Site Selection		10-25
Project Supervision	6 – 12 Months	25-50

Table 4.2: TRL 2 Format – schedule & budget

Figure 4.2: Practical TRL 2 Model [courtesy Ocean Energy Ltd]

TRL2 – Pre-sea trial stage gate requirements

- Accurately simulated PTO characteristics
- Performance in real seaways (long and short crested)
- Survival loading and extreme motion behaviour.
- Active damping control (may be deferred to Phase 3)
- Device design changes and modifications
- Mooring arrangements and effects on motion
- Proposed power take-off design and bench testing (Phase 3)
- Engineering design (Prototype), feasibility and costing
- Site review for Phase 3 and Phase 4 deployments
- Over topping rates

4.3 Technology Readiness Level 3 [addressing the Known – Knowns]

There is a growing agreement that before full scale pre-production prototype WECs are built and deployed, a large scale unit in the region of scale =1:4 should be tested at a benign outdoor site. [N.B. The waves are not benign relative to the model]. This step would be a main contributor to the title of this article since the machine should be a fully operational unit but the required budget an order of magnitude less.

The practical rationale for TRL3 is that sea states are lower, the test sites involve shorter boat trips and the support services required (harbours, support vessels etc) are also more readily available. The technical motivation is that it is very difficult to bench test the device's individual sub-systems, assemblies or components so this approach enables the machine to become a serviceable test rig.

An estimate of this TRL's time and budget is shown in Table 4.3 together with a model, or device, at sea (Figure 4.3). The people on deck indicate the device physical size.

Because these are fully operational electricity generating machines being tested in realistic conditions, TRL3 offers the opportunity for more that just power and technology proving. Not only can project management, manufacturing, deployment, servicing and maintenance techniques be practiced but also certification and insurance requirements, licensing and permitting issues together with environmental requirements will be experienced. Listed below are some of the key aspects of TRL3 activity.

It is essential that funding mechanisms to enable this TRL are included in country support policies. To reduce the fiscal risk it is recommended that this phase is conducted at an established test site.

Process Model: Phase 3		Scale: 1:10-15 or 1:1-4
SECTION	**TIMETABLE (Including Analysis**	**Budget (€000)**
Large Scale Facility	3 – 9 Months	500-1,000
Benign Site	6 – 18 Months	1,000-2,500

Table 4.3: TRL 3 Format – schedule & budget

Figure 4.3: Operational TRL 3 Model [courtesy Ocean Energy Ltd]

TRL3 – Pre-prototype stage gate requirements

- To investigate physical properties not well scaled & validate performance figures.
- To employ a realistic/actual PTO and generating system & develop control strategies.
- To qualify environmental factors (i.e. the device on the environment and vice versa.
- 1(Marine growth), 2(corrosion), 3 (windage and current drag).
- To validate electrical supply quality and power electronic requirements.
- To quantify survival conditions, mooring behaviour and hull seaworthiness
- Manufacturing, deployment, recovery and O&M (component reliability)
- Project planning and management, inc licensing, certification, insurance, etc

4.4 Technology Readiness Level 4 [addressing the Knowns]

Prototype scale testing commences in TRL4. The importance of these sea trials cannot be over stated since they must progress the device from a pre-production to a pre-commercial machine. It can also be seen that both the required budget and duration increase significantly in line with the shear scale of operations. This can be seen by the device in Figure 4.4 where offshore operations are now very serious activities. It would be expected that a utility or other large financial backer would be involved by this TRL.

It is not possible to cover all the requirements necessary for proving the device at TRL4, since it involves a full pre-production process verifying that the completed device is fit-for purpose under all headings. These would range from the overall design to individual component suitability, through to electrical production and quality of supply. Effectively, the machine has to satisfy the complex 'wave-to-wire' performance WECs must achieve if they are to be successful. However, it should not be expected that single units could ever repay the project cost; therefore a funding mechanism to support this period of development is extremely crucial to allow devices to successfully complete TRL4.

A testing centre infrastructure to support TRL4 is currently under development (see Section 5), especially in Europe. If these establishments expand with supply and support services, as it is expected, it would be (strongly) encouraged that sea trials are conducted at one of the centres to reduce the challenges facing heavy engineering operations at sea. As well as alleviating permitting, licensing and other ocean use issues the sites should offer easier grid connection that includes performance monitoring instrumentation. It is anticipated that service vessels and support industries will set up in these areas and quickly gain important experience in their fields, which device developers should then benefit from.

The list below provides a summary of some of the key performance elements to be considered during TRL4 testing. The list is by no means complete.

Prototype Device: Phase 4	Scale: 1:25-100
TIMETABLE (Including Analysis	**Budget (€000)**
6 – 12 Months	10,000-15,000
1 – 5 Years	~ 20,000

Table 4.4: TRL 4 Format – schedule & budget

Figure 4.4: Pre-production TRL4 Device [courtesy AWS Ocean Energy]

TRL4 – Pre-production stage gate requirements

- Hull seaworthiness and survival strategies
- Mooring and cable connection issues, including failure modes
- PTO performance and reliability
- Component & assembly longevity
- Electricity supply quality
- (Absorbed/pneumatic power-converted/electrical power)
- Application in local wave climate/conditions
- Project management, manufacturing, deployment, recovery, etc
- Service, operational and maintenance experience [O&M]

4.5 Technology Readiness Level 5 [addressing the future!!]

When a device successfully completes the rigorous technical sea trials the solo pre-production converter should have evolved into a pre-commercial machine ready for economic demonstration in TRL 5. By this stage matters have advanced to project rather than

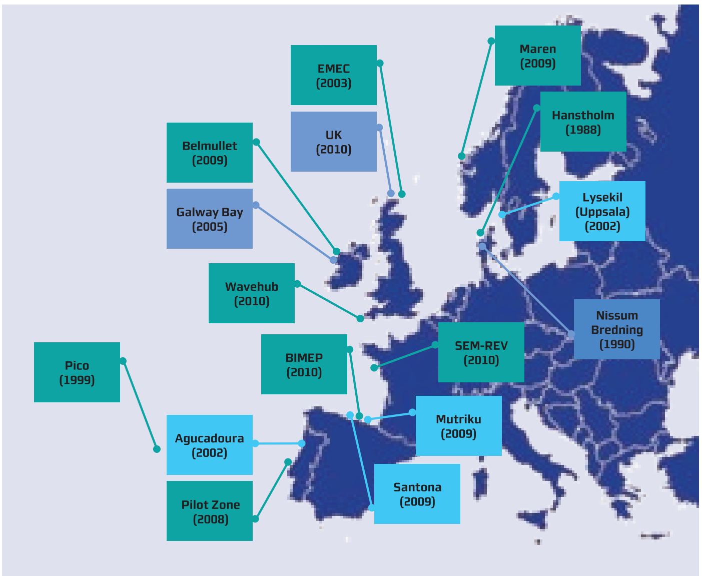

Figure 5: Proposed European Test Centres; GRAY =TRL3; GREEN =TRL4; LIGTH BLUE =TRL5

product development and will involve groups specialising in this work.

The technical risks in this TRL should be contained since it mainly involves combining several machines that have already been proven. However, although the likelihood of major failures is reduced the consequence of breakdowns can be considerable. The financial risks are less certain since it is the economic prospects that are under review. Business forecasts indicate that ocean energy parks will only become commercially viable when large arrays of devices (50 -100 MW) are deployed. The purpose of this phase is, therefore, to test small groups of devices that, if successful, can be expanded into a full electricity generating station.

There are two main technical components under investigation during this time. Firstly, can the intelligent power electronics controlling the output from each individual unit combine the supply in a way that stabilises the exported supply to the grid. Many theoretical studies have been conducted on this subject and comparison made with wind park output. However, only one wave energy array has been in operation for a limited period, so no empirical evidence yet exists to validate or verify the theories.

Secondly, the physical influence of one machine on another by the interaction through the medium they operate in. This can be particularly important in wave energy arrays since the radiated wave from a single device spreads radially along the ocean surface. To some degree this interaction will be specific to a particular type of machine so generic studies should have been conducted in one of the earlier TRLs to estimate the optimal spacing and layout criteria for the park if the issue is found to be important.

The stage gate evaluation criteria requirements at this time are extensive so just a key summary list is presented below.

TRL5 – Pre-commercial stage gate requirements

- Multiple units performance
- Device array interactions
- Power supply interaction
- Environmental impact issues
- Full technical & economic due diligence

5. Infrastructures

A strong technical support structure is advantageous to implement the TRL schedule efficiently. However, as with the device development guidelines, until post-2000 there existed few large-scale sites where wave energy machines could be tested.

Indoor hydraulic tank facilities for TRLs 1 & 2 investigations were less of a problem but few centres specialise in ocean energy testing for either wave or tidal models. Even today there is no single establishment with whom a device developer can work to move efficiently and cost effectively through the early stages of development. This situation may improve over the next few years as disparate European testing centres are attempting to form a distributed network through which a developer may progress the design of a WEC through all TRLs. A similar co-ordination of effort is under review in the USA.

There would be several advantages to such a technical network but, of particular merit, would be the implementation of the established testing programmes as outlined above. At present there is no universally established test protocol so testing centres apply their own. Projects, such as the EU-supported EquiMar consortium and a US Department of Energy's initiative (through NREL) are attempting to correct this deficiency, by drawing up details for each TRL, including the continuation stage-gate criteria. Eventually such documents can reside with the centres to ensure consistent and comparable results.

Prior to the new Millennium there was certainly a dearth of outdoor test areas where the later and larger size TRL trials could be conducted. Only two sites were available pre 2000 (Figure 5). Both of these were in Denmark and at that time they were not registered externally as official test centres.
There may still be a shortage of large-scale TRL3 test sites (GRAY boxes) though some of the continental full-scale pilot zones now offer the opportunity for short-term testing of quarter-scale machines in the calmer seasons.

There is also only one pre-production sea trial site for small array testing, the Wavehub in Cornwall, England, which will become operational in 2011. However, the sea areas marked in LIGHT BLUE represent early pre-commercial wave parks, where device interaction investigation can take place. Unfortunately the public availability of the data is uncertain.

6. Towards the Future

There is good reason to be cautiously optimistic about the prospects of marine energy technologies supplying significant amounts of clean electricity.

This optimism can be supported by the number of devices that are progressing through a development programme to begin sea trails at, or close to, full-size prototype scale. If only one or two achieve expectations at the pre-production stage the objective of harness the world's ocean power potential should become achievable.
The caution is based on the funding mechanisms. Although the current set of pioneering devices must be the units that prove the technical and practical possibility of extracting ocean energy they may not be the machines that are finally deployed on a wide scale. It is important therefore to maintain support systems that will allow the companies to re-investigate fundamentals or enable new entrants into the industry.

The stage-gate application through the Technology Readiness Levels should assist the process as an evaluation methodology that will enable funding to be appropriately focussed at each of the TRLs.

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Ocean Energy as Ocean Space Use – Only Conflicts or Also Synergies?

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The Future of Ocean Space: a Crowded Usage?

The increasing ambitions of implementing ocean energy technologies on a large-scale have led to discussions about the conflicts of use of the ocean space, mainly with respect to traditional competing uses, but also among the new 'competitors' in the field of maritime renewables. To date, this situation has been generally recognised at a generic, but not detailed, level (see e.g. Waveplam, 2009).

With terrestrial resources approaching their physical limits, ocean space has increasingly been considered as a last resort for a number of vital resources of modern society, in particular for energy conversion, minerals, biomass and food. Territorial waters are subject to increased economic interest, which is why tools like Marine Spatial Planning (MSP) and Integrated Coastal Zone Management (ICZM) have become major issues on the political agenda in the European Union (EU) and beyond. While ICZM has been implemented for a long time in most developed coastal areas, future-oriented and consistent decision-making needs to be extended towards the offshore region in the present context. Instead of some usages replacing others, it is likely that traditional usages of ocean space continue or even increase, while new and competing uses will equally require large areas.

Such a scenario requires a new level of sensibility on the decision-making level, both with respect to priorities, possible co-existences and cross-border aspects. On the national level, some countries have started to implement detailed and structured approaches to regulation and avoiding conflicts of ocean space use, including the emerging sector of electricity generation from marine renewables. In particular in the UK, the Department for Environment Food and Marine Affairs (DEFRA) has established a widely accepted definition of the term Marine Spatial Planning, showing the ambitious targets of the process:

> "Marine spatial planning provides an opportunity to take a strategic plan for regulating, managing and protecting the marine environment that addresses the multiple, cumulative and potentially conflicting uses of the sea".

The process of yielding a binding legal framework to this extent, originated in the year 2002 (DEFRA, 2002), has recently yielded the Marine and Coastal Access Act in 2009 (DEFRA, 2009).

The rapid increase of large-scale offshore wind farms contributed to the importance that this issue has been given in the UK, and certainly the existence of high-level discussions involving several public documents and consultation periods has, in turn, been beneficial for the acceptance of large-scale offshore wind farms. However, each technology has its own specific coastal and maritime space issues, and geographic factors strongly influence the usage scenarios involving marine renewables.

Therefore, there is a strong need for more detailed technical inputs for such documents, as well as for an integration of cross-border relevant aspects and a global understanding of priorities and co-existence.

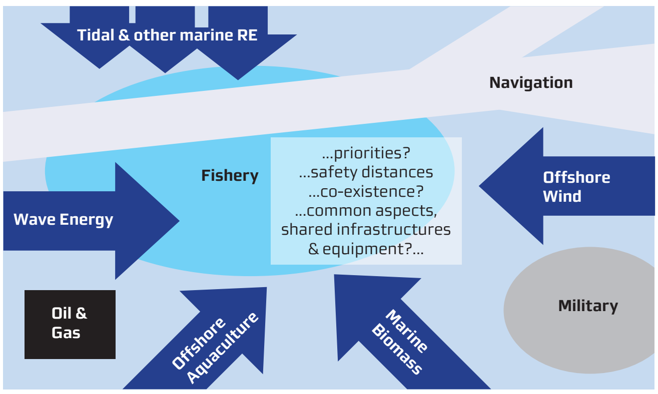

Figure 1: Sketch Of Increasing Density And Variety Of Ocean Space Uses: The New 'Competitors'

The Need For More Structured Planning & Consenting

Every sector considers its own performance and contribution as the most relevant to society, and as long as its economic activities remain autonomous, the requirement for co-existence or even synergies with other sectors, potentially competing for access to the same areas, is not a priority. In this context, ocean energy will not only 'compete' with existing ocean uses but also with other new activities considered vital for modern society. Therefore, quantitative and objective means of measuring the (socio) economic value and consequently attributing priority usages for certain areas will be an important tool for future marine spatial planners. Socio-economic evaluations exist for traditional sectors (e.g. fishing), but others are difficult to quantify (e.g. military uses). The socio-economic value of marine renewable energies still has to be evaluated, although conventional offshore wind (bottom-fixed farms in shallow water; <40m) provide some evidence. If an acceptable approach for such quantification can be found for the entire range of competing uses, the most optimal and beneficial uses of ocean space can be guaranteed.

Given the scenario of potentially 'crowded' territorial waters, the most interesting areas for marine renewable energy conversion, namely shallow to intermediate water depths (30 – 200m) relatively close to the coast, are intrinsically subject to the highest competition. From the perspective of ocean energy and its comparatively weak lobby, it is vital for the emerging sector to create awareness of its needs, and to procure strategic allies since there are no presumed preferential rights. Further, the high capital-intensity connected with moderate revenue and capital return performance in the early years of development make it vital for ocean energy to be proactive in highlighting and pursuing potential synergies with other sectors. In addition to direct economic benefit in case of synergetic co-existence, ocean space can be used in a more efficient way, which in turn should count in favour of such combinations in the process of MSP. A good example of the growing interest in such synergies is the recent call of the European Commission for projects that address combined platforms for wave and offshore wind energy.

Overall, more detailed consequential investigations are needed in order to yield a reasonable and efficient co-existence of future sea uses. Thus, MSP should be enabled and take into account the following aspects:

(i) Quantified (socio) economic value (e.g. per square km) of different usages; the outcome must be a directly comparable quantity, however local and regional priorities and in particular environmental acceptance must be taken into account;

(ii) Existence of synergy potential between different usages based on their space use and technical characteristics with respect to dimensions, materials, installation and O&M needs (increase in value for any combined uses).

The remainder of this article is an attempt to outline the needs for ocean space and characteristics of the most likely major potential 'rivals' of ocean energy (in particular wave energy, due to its expected large-scale implementation in territorial waters) for future ocean space use, as well as to highlight some potentially important synergies. Simultaneously, it is a call for more detailed and pro-active investigations on technical and procedural synergies of ocean energy with other usages.

Existing Uses of Territorial Waters

In the following section, the expected usages of the ocean space are briefly outlined, in particular with respect to their characteristics regarding potential conflicts and co-existence, or even synergies, with ocean energy. It should be noted that typical 'conflicts of uses' are no-go areas, some of which are not generally linked to a certain usage or not easy to evaluate on the background of the purpose of this article. Such obstacles can be existing cable routes (mainly for telecommunication but also electricity transmission cables), pipelines, scientific research areas, including sites of (potential) archaeological interest and specific biosphere reserves, as well as dredge spoil disposal sites and their safety perimeter. Such conflicts are not the scope of this discussion, as there is neither a way to reasonably quantify their comparable benefits, nor to procure synergies with ocean energy.

Navigation & Safety

Large-scale wave energy farms might be planned in areas that are intensely used for navigation purposes. The characteristics of commercial ship traffic and leisure or small craft interaction are distinct:

- **Maritime Transport / Cargo**
  In busy navigation routes, any obstacle increases the potential hazard of ship collisions and, based on the present mindset of shipping authorities, ocean energy would be considered a danger within a rather large perimeter around shipping routes – even outside the main routes. In particular in the North Sea and in the vicinity of more industrial re-

gions with major ports, this may become a major constraint for ocean energy.
On the other hand, advances in control and navigational warning systems can significantly improve this situation, once the navigational sector gets accustomed to the additional infrastructures at sea. At such a stage, even positive effects may arise regarding navigational safety and even maritime control issues: the marker systems of wave farms could incorporate modern communication systems, and assume the function of navigational guidance. Further, farms distributed relatively widely over the open ocean could play an important role in better controlling the common practice of illegal discharges of cargo ships, or even in ad-hoc actions in oil spills, preventing major damages to the environment.

- **Leisure/Recreational Boating:**
  Leisure boat (yacht) traffic can be difficult to tackle, also due to a lack of regulation and lower levels of professionalism (e.g. lower standard of navigational discipline and technical equipment), compared to commercial navigation. On the other hand, if active safety and communication capabilities are incorporated in the marker systems, even an improvement of yachting safety can be achieved (see above). For small crafts in general ocean energy infrastructures may provide an additional item for emergency assistance, several miles out in the sea.

Fishing

Fishing is by far the most widespread and well-established usage of ocean space, and, due to the strong traditions of the sector and the constantly increasing need for seafood, it is considered a vital activity. In addition to the same navigational risks as for other ships, the opposition of fishermen communities to potential no-go areas due to ocean energy farms is a widely discussed issue.

- **Industrial/Trawling:**
  In wide areas of the coastal and territorial waters, the dominant use of ocean space is commercial fishing, often by trawling fleets. In some regions considered appropriate for ocean energy, such as the Portuguese coast, the only traditional ocean space use has been fishing, so the fishing industry might have difficulties to accept other new and competing uses. The opposition of the commercial fishermen community to marine renewables could arise from the potential requirement for relatively large no-go areas for trawling, because of the specific potential damage of anchors, mooring lines, measurement devices and other infrastructural elements by the fishing nets.
  On one hand, a certain opposition is comprehensible if looking at short-term and company-specific economic profit. On the other hand, independent evaluations have to reason whether or not such opposition is justified and how priorities should be fixed. Such a process should take into account (i) the direct economic benefit of each activity, and (ii) whether there is in fact a conflict, or whether synergies between these uses could even outweigh the conflict potential. From a pragmatic viewpoint, an increased presence of 'smart' offshore infrastructures would also benefit the fishing community, as verification of catch quota and mutual respect of boundaries increases the fairness of this activity. It is further likely (though not yet proven) that large no-go areas caused by the ocean energy farms function like sanctuaries and actually improve the habitat to an extent that livestock may recover significantly. Based on the continuous decrease of livestock of important fishing species, such a scenario would directly benefit the fishing sector.
  In any case, there will be the need to reconcile large-scale ocean energy with the fishing industry, and synergy potential does not seem to be significant from a technical viewpoint.

- **Artisanal Fishing:**
  Issues like ocean space access restrictions for the 'general public' in order to enable an economic activity are usually emotive and in particular local fishing communities can have strong lobbying capacity. On the other hand, the artisanal fishery as trade is factually threatened with extinction in many coastal areas, and due to the profound knowledge of the marine environment and navigation equipment, affected communities have an excellent potential for employment in the rising marine energy industry after slight retraining actions.
  If active and early dialogues with such artisanal fishing communities succeed, wave energy farms might not be perceived as a threat but, in the best case, as an opportunity.

Military and Surveillance

The existence of designated areas for military use typically excludes the implementation of marine renewables. On one hand, it must be verified – on a case-to-case basis – to what extent such areas need to persist in the same dimensions and, to the same extent, as compared to times where no other large-scale uses than fishing existed. In many cases, a possible relocation of such areas further offshore might be a valid option. On the other hand, with ocean energy installations becoming a reality along large parts of the coastlines, military field exercises should also recognize this reality, so in some cases superposition might be acceptable.

Certainly there is synergy potential for other military uses, namely related to surveillance of traffic and intrusions, including the increasing problem of drug traffic. Properly instrumented (radar, visual and acoustic devices), offshore wave energy farms can substantially contribute to monitoring territorial waters. It should be reminded that some wave energy applications have been supported in recent past having in view autonomous military uses.

Oil & Gas Exploration & Production

To a similar extent to fishing, oil & gas exploration and production activities have dominated some areas of ocean space. The relationship between these activities and ocean energy is two-fold:

- In active production areas, there may be a restriction on ocean energy farm density (due to exclusion zones), but no general exclusion of such installations. In fact, the offshore oil & gas sector initially looked into marine renewables for autonomous power supply. For example, the Beatrice (www.beatricewind.co.uk) offshore wind farm project was mainly driven by this idea. So ocean energy and hydrocarbon production may have some attractive synergies.
- In case of exploration activities in areas where no resources have yet been detected, the priorities need to be re-evaluated, as it is certainly unacceptable to reserve such areas for several decades, thus excluding other uses. However, even in case of later detection, a co-existence may be possible, if taken into account early.

In both cases, ocean energy can contribute to fulfil the high-energy demands of offshore oil & gas activities, partially offsetting the rivalling factor of ocean space use.

Oceanography and Other Marine R& D

Provided that ocean energy does not significantly impact with the physical and biosphere environment, more synergies than conflicts can be expected for oceanographic and other R&D activities. Except for specific large-scale baseline studies, where a native environment is required for proper results, marine renewables infrastructures can serve as monitoring stations for meteorology, water properties and livestock survey, among others.

Competing New Uses (Aspirants)

Marine Renewable Energy – Offshore Wind

Offshore wind energy has been the fastest growing renewable energy source and is a reality in relatively shallow waters, mainly in the UK and the Baltic regions. The expansion of the 'shallow-water' technology is somewhat limited and many coastlines are too deep for further growth. On the other hand, particular floating wind farms are likely to become a major contestant for areas that are suitable for wave energy. Several technologies (Hywind, www.statoil.com; Sway, www.sway.no; www.bluehgroup.com; WindFloat, www.principlepowerinc.com (Figure 2)) have reached a credible development status, and their technical properties indicate large potential for combined use with ocean energy devices.

Figure 2: Artist's Impression Of Windfloat Concept: Various Technical Synergies With Wave Energy Devices
(Picture Courtesy of Principle Power Inc.)

Floating wind farms are typically moored in 50 – 200m deep water, and their distance would generally allow wave farms to be installed in-between (in an advanced stage, once mooring systems of different floating devices might be combined). There are further possibilities of direct integration of Oscillating Water Columns (OWCs) in the structures of floating wind farms, and floating and submerged point absorbers might be used for catenary mooring systems. In addition to the more efficient use of materials and equipment, common installation and O&M activities can be explored.

Marine Biomass

Marine biomass is often included in the term of 'aquaculture' (see next section), while biomass itself is a term usually connected to renewable energy. However, in this article it is considered separately, being aquaculture related to fish and seafood (livestock) farming. Recently the large-scale 'farming' of marine biomass in offshore installations has become the subject of substantially increased interest, partly as a consequence of its potential for CO_2 sequestration. The development of industrial-scale algae bio-reactors is starting to be planned for production of carbon-neutral bio-fuels, high value food colourings, pharmaceuticals, cosmetics, dietary supplements, edible seaweed, animal feed, soil improvers, and fertiliser. Ultimately, area-wide implementation of algae cultivation has been proposed for direct CO_2 sequestration.

Figure 3: Example Of Multifunctional Maritime Traffic Zones As Proposed By AWI
Picture from www.awi.de/en/research/new_technologies/marine_aquaculture_maritime_technologies_and_iczm/

Among other research activities world-wide, the German Alfred Wegener Institute (AWI) (www.awi.de) has investigated offshore cultivation of marine macroalgae under harsh environmental conditions since the mid-nineties, and already proposed multifunctional ocean space use in connection to offshore wind farms several years ago, including solutions for traffic organisation in such areas (Figure 3; Buck et al., 2004).

In addition to low potential competition for ocean space, since marine biomass cultivation could be implemented further offshore, marine biomass production has an obvious synergetic potential in connection to ocean energy, in particular with respect to the joint use of offshore infrastructures (e.g. mooring lines, monitoring devices) and joint O&M. Further, marine biomass cultivation could potentially be incorporated in ocean energy installations, due to the large variety of potential technical requirements. Finally, ocean energy devices could be used to provide energy for the marine biomass cultures, which was recently announced as one of the commercial approaches to synergetic marine biomass and ocean energy production by the Marine Sector of the British C-Questor group (www.cquestor.com).

Offshore Aquaculture

Open water offshore aquaculture for fish and seafood production on a large-scale has been increasingly considered a sustainable alternative for satisfying the massive needs of human consumption. While open-ocean fishing is reaching physical limits and some species are moving towards extinction, pond aquaculture is land-intensive and expensive, and the quality of the products is questionable. Due to being in open waters, offshore cages are subject to natural water circulation and quality, health and environmental issues are drastically reduced. Offshore aquaculture had been a vision for more than a decade, however only in recent past significant advances have been made, for example through the Hawaii Offshore Aquaculture Research Project (HOARP, see Billig, 2009 & Figure 4) that uses a large bi-conical steel cage for survivability in waves up to 8m.

Meanwhile, credible commercial approaches to submerged offshore cages have been developed, for example the OceanGlobe from the Norwegian company Byks (Figure 5; www.byks.no), the Aquapod from the US company Oceanfarmtech (www.oceanfarmtech.com), and the Sea Station from the US company Oceanspar (www.oceanspar.com).

Figure 4: HOARP Demonstration Project
Picture from www.oar.noaa.gov/spotlite/archive/spot_hawaii.html

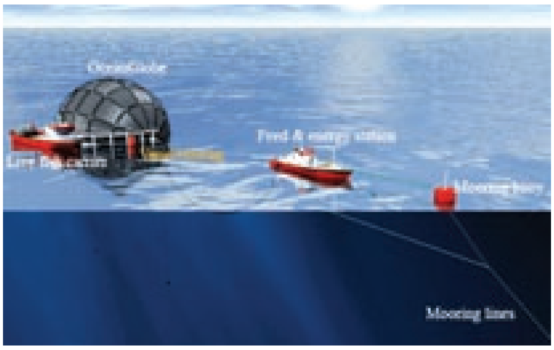

Figure 5: Artist's Impression of OceanGlobe Installation
Picture from www.byks.no

Goudey (2008) and Kite Powell (2008) give a comprehensive overview of the state of the art and currently most relevant issues of the sector. Despite its large potential and technical viability, offshore cage aquaculture faces a dilemma similar to offshore renewable energies: costs are still multiples of costs for aquaculture in nearshore protected waters, mainly as consequence of the high mooring and O&M costs. Successful implementation of automated operating procedures for minimising labour, improved safety and further reduction of environmental impacts are the most relevant items for making offshore aquaculture viable, and this could well be possible by sharing ocean space and infrastructures with ocean energy, in particular large-scale wave energy farms. To a similar extent like marine biomass, ocean energy can equally be used to power large-scale open water aquaculture.

Conclusions

The increasing density of ocean space use and the relatively low priority ocean energy has experienced in the political agenda to date call for improving the growing sector's positioning for future implementation phases. In order to ensure strong, sustainable growth of ocean energy, its secondary uses, and synergies with existing and other new activities, have to be fully explored. In particular, wave energy and floating offshore wind farms appear suitable to coexist; in addition, marine biomass farming and/or large-scale offshore seafood aquaculture hold a large potential for technical synergies with wave and/or offshore wind farms. In general, these synergies consist of common use of mooring systems, installation processes, O&M equipment and personnel. In the early implementation phase of marine energy farms such synergies can naturally not be exploited, as survivability and other technical issues need to be fully addressed first. However, once technical solutions for such combined uses are developed, the viability and acceptance of ocean energy and other uses will be substantially increased. Therefore, such synergies must be investigated at an early stage and stakeholders from different fields should be incentivised to collaborate on this issue.

In this context, current legislation and consenting procedures appear biased towards traditional, or simply the most capital-productive uses, which calls for correction towards more objective and neutral evaluation procedures for deciding upon priorities for ocean space use. Such procedures should include a quantification of the weighted socio-economic benefit of each use. Further, the factor of secondary uses and synergy potential should be accounted for by default in future actions of marine spatial planning. Finally, a much stronger international collaboration must be enforced to enable an integrated approach, not limited to European waters.

Acknowledgements

The author acknowledges the support by the EC-Intelligent Energy-funded project Waveplam.

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Overview of Global Regulatory Processes for Permits, Consents and Authorization of Marine Renewables

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Note: The views discussed in this paper are entirely the author's own, and do not represent the official position of OREC.

Executive Summary

Within the past two years, a number of first generation, commercial marine renewables projects came online, delivering power to the grid. These projects include: Verdant Power's RITE project,[1] Pelamis' Aguçadoura Wave Park,[2] Marine Current Turbines' SeaGen Project at Strangford Lough,[3] and Aquamarine's Oyster.[4]

Unfortunately, international regulatory processes for siting marine renewables have not kept pace with technological advancements. In many countries, deployment-ready projects face costly and protracted permitting procedures by multiple agencies, each with their own unique legal and regulatory requirements. Few regimes provide an expedited system for deploying smaller or early stage commercial arrays. In addition, most marine renewables find themselves in a "Catch-22" situation: regulatory bodies are reluctant to grant authorizations without information about project impacts, but developers cannot provide this information without first getting projects into the water to gather data on impacts. Finally, marine spatial planning (MSP) – a tool designed to facilitate coordinated decisions about use of marine resources on a programmatic level rather than case-by-case basis – is gaining traction, and raising questions about whether MSP will expedite marine renewables development through advance planning or interfere by potentially delaying near term development or putting promising sites off limits.

This paper provides an overview of the regulatory process and unique challenges for marine renewables in different parts of the world. The first part of this paper surveys the regulatory process in various countries governing permits, consents and other necessary authorizations for marine renewables projects. As Part I will discuss, most countries' existing regulatory systems share features such as environmental review, opportunities for stakeholder input, examination of competing uses and a method for acquisition of site access and adequate property rights to construct the project. Likewise, in recent years, many countries have enacted legislation to facilitate renewables' ability to secure grid access, which is another necessary component of the regulatory process. Part II will discuss obstacles to expedited permitting – such as lack of co-ordination between agencies or "regulatory overkill," *i.e.*, where projects are subject to extensive review and mitigation conditions disproportionate to the potential harm. Part II briefly evaluates various options to advance marine renewables development such as marine testing beds with blanket consents, pilot project licensing and adaptive management, strategic environmental assessment and coastal and marine spatial planning.

I. Summary of Regulatory Process

This section will describe the following components of the regulatory or process: (1) legislation or regulations that govern the consent or approval process (including any special processes for demonstration projects); (2) procedure for obtaining a lease or rights to use lands for the project, (3) review of project impacts, including environmental, navigation, fishing and recreational use and (4) grid access. The table below summarizes the discussion:

[1] Verdant Power Website, http://verdantpower.com/what-initiative/ (last visited December 4, 2009) (describing two year demonstration operation from 2006-2008 of 6 unit Roosevelt Island Tidal Energy project in East River, New York).

[2] The Aguçadoura Wave park, comprised of 3 x 750 kW units operated from September through November 2008, before being removed. Due to financial difficulties of the parent company, the project remains out of commission. See http://en.wikipedia.org/wiki/Aguçadoura_Wave_Park

[3] Marine Current Turbines 1.2 MW Seagen unit was deployed in Strangford Lough in April 2008 and remains in operation. See http://www.marineturbines.com/18/projects/19/seagen/ (accessed December 4, 2009).

[4] In November 2009, Aquamarine Power launched the Oyster at EMEC, which is feeding power to the grid through a shore-based hydropower project powered by water pumped from the Oyster wave energy device. See http://www.aquamarinepower.com/news-and-events/news/latest-news/view/112/scotland-s-first-minister-launches-oyster/ (accessed December 4, 2009).

Country	Authority for Consents	Special processes	Lease	EA	Grid Access
US	FERC issues permits and licenses under Federal Power Act	Pilot project license for small (< 5 MW) demonstration projects; one year processing time.	State leases for state submerged lands, MMS lease on Outer Continental Shelf	Yes, by FERC for licenses and MMS for leases.	Yes, under FERC Interconnection Rules
Canada	Varies by province; Ontario establishes Renewable Energy Facilitation Office (REFO) for review	Renewable Energy Approval (REA) can issue in 6 months time.	Granted by provinces	Yes, though varies by province. Nova Scotia has SEA for tidal projects.	Yes, under Ontario Green Energy Act
UK	Marine and Coastal Access Bill for projects <100 MW; Planning Act for projects > 100 MW Scotland is developing similar bill.	Consolidated process by Marine Management Organization (MMO) for smaller marine renewables projects	Seabed lease or site option agreement from Crown Estate	Required for all marine renewables. Scotland, Northern Ireland preparing SEAs for marine renewables	Department of Energy is developing new regulations for grid access for offshore renewables.
Portugal	Decree Law No. 5/2008 for Pilot Zone	Pilot Zone for demonstration, pre-commercial and commercial wave energy devices up to 250 MW	Pilot Zone access	Environmental Incidence Study for Pilot Zone	Yes, in Pilot Zone
Denmark	Not discussed	One stop shopping	Not discussed	Yes	Yes
Australia	Authorization under Coastal Management Act	Not at present	Not discussed	Yes	Not discussed
NZ	Authorization under Resource Management Act, with regional councils issuing consents	Yes, 2009 amendments include streamlining decisions	Not discussed	Yes, all applications require Assessment of Environmental Effects of project impacts	Not discussed

A. United States

1. Authority for consent

In the United States, the Federal Power Act (FPA), 16 U.S.C. 791 *et. seq.* governs licensing of marine renewables projects. Under the FPA, Federal Energy Regulatory Commission (FERC) may preliminary permits and licenses for marine renewables. A preliminary permit enables a developer to study a site for three years and maintain priority to apply for license over competing applicants but does not authorize construction of a project (Federal Power Act, 16 U.S.C. sec. 800). As a result, a preliminary permit does not provide any opportunity to test projects in real world conditions. A FERC license, by contrast, allows a developer to construct and operate a project, generally for a term of up to 50 years. But the process for obtaining a license is lengthy (as long as three to seven years) and requires data on a project's potential impacts, which are often unknown until a project is deployed and observed.

Recognizing the limited options for demonstration projects, FERC developed two alternatives. The first alternative, known as "the Verdant exception"[5], allows a developer to deploy and operate a small (less than 5 MW) project for 18 months or less to gather data to support a license application, so long as the developer agrees not to sell power to the grid during the test period.

The second alternative is the FERC created "pilot license process" for new technologies in 2007. A pilot license has a five-year term, a processing time of one

[5] Verdant Power, FERC Decision, 111 FERC para. 61,024 (2005). The Verdant exemption was named for Verdant Power, which first asked for this policy. Now established, it is available to all developers.

year, limited study requirements up-front but rigorous post-deployment monitoring requirements. At the end of the five-year pilot license term, a developer has the option of removing the project or applying for a long-term license at the site. *See* FERC Hydrokinetic Pilot License Process at http://www.ferc.gov/industries/hydropower/indus-act/hydrokinetics/energy-pilot.asp. Presently, three United States developers – Verdant Power, Snohomish Public Utilities District and Ocean Renewable Power Corporation – are pursuing pilot licenses for tidal sites in Washington State and Maine.

See http://www.ferc.gov/industries/hydropower/indus-act/hydrokinetics.asp

2. Property Interests/Site Access

The FERC process authorizes project operation but does not confer property rights for constructing the project. For projects located on "state submerged lands" – that is, lands up to three miles off shore (with the exception of Texas and the West Coast of Florida where states own lands up to ten miles offshore) – a developer will typically obtain a land lease or rights of usage from the state. Projects beyond these limits are located on the Outer Continental Shelf, where a developer must obtain a lease from the Minerals Management Service (MMS). In April 2009, MMS issued rules for grant of leases and also entered into a Memorandum of Understanding (MOU) with FERC to coordinate the leasing process with the licensing process. Under the MOU between FERC and MMS, a developer must secure a lease from MMS, before it can receive a FERC license.

3. Environmental Review

In the United States, federal agencies that issue a license must prepare an environmental analysis to assess the impacts of a project on the surrounding environment and other uses. The FPA also requires FERC to review the effect of a project on navigation and to consider whether it makes best use of the waterway (FPA, Section 803). Projects must also comply with a variety of federal environmental laws, such as the Endangered Species Act (protects endangered species), the Coastal Zone Management Act (CZMA – ensures that project is consistent with state plans for use of coastal areas), the Clean Water Act (protects water quality), whilst abiding by state environmental regulations as well. In addition to the FERC license and a land lease, developers must also obtain authorizations from the agencies that administer these federal statutes. There is no process for coordinating issuance of a FERC license and issuance of a CZMA authorization (issued by the state) or a water quality certificate and, as a result, the license process is quite lengthy.

4. Grid Access

For projects that connect to the interstate grid, FERC has power, under the Federal Power Act and FERC's own regulations, to oversee interconnection. FERC established a straightforward protocol that developers must follow to obtain grid access; the rules for smaller generators are not complicated and the process is relatively quick. [*See* FERC Regulations on Interconnection,http://www.ferc.gov/industries/electric/indus-act/gi.asp]. As marine renewables projects expand in size, they will impose greater demands on the grid.

Marine renewables projects may face longer "queues" for access, as the utility or the regional transmission system operator[6] evaluates how to incorporate large amounts of new and variable power into the system.

B. Canada

1. Consents and Environmental Review

In Canada, projects are approved and monitored by a series of federal and provincial environmental agencies and laws. Permitting processes differ by province, with regulations too varied to summarize in detail. Generally, projects are subject to some type of environmental assessment – either an individual Environmental Assessment (EA) (for larger projects), a class EA (evaluates impacts of classes of activity) or screened EA (where projects falling below certain impact levels are exempt from further review. An Environmental Assessment includes an evaluation of effects on fish habitats under the Federal Fisheries Act and on endangered species under the Species at Risk Act. Navigational impacts are also evaluated by the Navigable Waters Protection Division.

Some provinces have made modifications to these general practices. In September 2009, Ontario's new Green Energy Act took effect, with significant improvements for streamlining of siting of tidal energy projects. The Green Energy Act establishes a Renew-

[6] In some parts of the United States, the grid is operated by a regional transmission authority, rather than an individual utility)

able Energy Facilitation Office (REFO) to assist renewable developers by connecting them with resources in other government ministries and agencies and providing information on government incentive programs. The Act creates a comprehensive "renewable energy approval" (REA) which consolidates environmental review processes, creates procedures for stakeholder input and exempts renewables projects from municipal zoning requirements, which had previously thwarted expeditious permitting.[7] As a result of the changes, developers can obtain required permits in six months' time.[8] There is even discussion of a six-month guarantee for processing approvals.

In Nova Scotia, tidal project development begins with a strategic environmental assessment of a site, after which access is awarded to a company through a competitive process.[9] The developer must then obtain all necessary permits to site the project, with fewer rigorous up front requirements for test facilities (which are subject to post-deployment monitoring).

2. Property Rights

In Canada, offshore Crown lands are controlled by the adjacent coastal province, which has powers of disposition. Provinces have different policies for granting use of Crown lands for marine renewables projects, with eased requirements for test or demonstration projects.[10] Most provinces require developers to pay a fee for leases for commercial tidal projects.

3. Grid Access

In Ontario, the Green Energy Act established a feed-in tariff, which also provides access to the grid. In other provinces, standard offer contracts for power purchases are available.

C. Europe

1. United Kingdom

a. Consents and Environmental Review

In November 2009, the United Kingdom's Marine and Coastal Access Bill received Royal Assent. The new law consolidates licensing of marine renewables of 100 MW or less within the newly created Marine Management Organization (MMO), thus eliminating the need for multiple consents under both the Food and Environmental Protection Act and the Electricity Act.[11] For projects larger than 100 MW (known as "nationally significant infrastructure projects"), the 2008 Planning Act establishes an Infrastructure Planning Commission to streamline the licensing process.[12]

In the UK, there are two types of environmental review: strategic environmental assessment (SEA) prepared by the government to evaluate impacts of marine renewables on a system wide basis, and an Environmental Impact Assessment (EIA), prepared by the developer addressing site specific impacts.

All marine renewables projects require an EIA. At this time, the UK does not prepare a SEA for marine renewables, because the impacts are yet unknown that the SEA would not produce any definitive data to inform siting decisions. The UK prepares a strategic environmental assessment (SEA) for offshore wind, and will likely prepare an SEA for marine renewables prior to the siting of large scale arrays.[13]

The Marine and Coastal Access bill has limited applicability in Scotland, Northern Ireland and Wales. Scotland is developing a similar a Marine Bill that will also streamline the licensing process and adopt a one-stop shopping approach.[14] In contrast to the UK, both Scotland and Northern Ireland are preparing SEAs that will include marine renewables.[15]

[7] See Green Energy Act (September 2009) (online at http://www.elaws.gov.on.ca/html/statutes/english/elaws_statutes_09g12_e.htm; additional information at http://www.greenenergyact.ca/Page.asp?PageID=122&ContentID=1360&SiteNodeID=243)

[8] *See* http://greenenergyreporter.com/2009/02/ontario-introduces-sweeping-green-energy-reforms/ (describing that elimination of municipal regulations will allow for six month processing).

[9] *See* http://www.gov.ns.ca/energy/resources/EM/tidal/Tidal-Policy-Framework-Nova-Scotia.pdf.

[10] *See e.g.*, New Brunswick Policy for Allocation of Crown Land for in-stream tidal projects at www.gnb.ca/0078/policies/clm0192007e.pdf Ontario crown land policy, http://www.mnr.gov.on.ca/en/Business/CrownLand/2ColumnSubPage/STEL02_165785.html.

[11] *See* Marine and Coastal Access Act (2009) online at http://www.opsi.gov.uk/acts/acts2009/pdf/ukpga_20090023_en.pdf, BWEA Summary Report (October 2009) at www.bwea.org.

[12] *See* Planning Act, http://www.opsi.gov.uk/acts/acts2008/ukpga_20080029_en_1.

[13] *See* http://www.offshore-sea.org.uk/site/scripts/documents_info.php?categoryID=39&documentID=5 (January 2009)(describing SEA process).

[14] *See* http://www.scotland.gov.uk/News/Releases/2009/04/29162907 (describing introduction of Scottish Marine Bill) (April 2009).

[15] *See* http://www.sei.ie/Renewables/Ocean_Energy/Offshore_Renewable_SEA/ (describing Irish SEA); http://www.seaenergyscotland.net/ (Scotland's Marine Renewable SEA).

b. Property Rights

Developers wishing to deploy a wave or tidal device or small array of up to 20 devices with capacity of less than 10 MW in UK waters or Renewable Energy Zone (REZ)[16] beyond 12 nautical miles, must obtain a seabed lease or site option agreement from the Crown Estate.[17] To obtain a lease, developers must show that the site is suitable for deployment of a marine energy device/array and provide a business plan, with a timetable of steps leading to deployment. Currently, the Crown Estate is opening large swaths within the REZ for offshore wind development off the coast of the UK. In 2008 the Crown Estate opened the first competitive bidding round for acreage to deploy wave and tidal energy projects in the Pentland Firth off the NE Scottish mainland.

Leases for test and demonstration projects will be short term, generally up to seven years. Rent will be discounted for the initial term of a demonstration lease.

c. Grid Access

The Department of Energy is developing a new regulatory regime for offshore electricity transmission, exploring ways for the capital cost of grid connection to be borne by the offshore transmission owner, rather than the marine energy project developer, who would just pay an annual charge. [18]

2. Portugal

a. Consents and Environmental Review

In Portugal, Decree Law No. 5/2008 establishes a Pilot Zone for the installation of demonstration, precommercial and commercial wave energy devices with rated capacity of up to 250 MW. The Pilot Zone is located 120 km north of Lisbon, off Sao Pedro de Moel and covers 320 km^2.[19] The Pilot Zone will be connected to the grid and will be managed by REN (*Redes Energéticas Nacionais* – National Energy Networks, S.A.). REN is responsible for licensing in the Pilot Zone, with regulatory processes varying, dependent upon whether a project is a pilot or commercial project. The licence process should be accompanied by an Environmental Incidence Study that is a less demanding administrative instrument than the Environmental Impact Assessment.

3. Denmark

Denmark's consent process for wave energy projects follows a one-stop shopping procedure used for offshore wind.[20] In issuing permit for wave projects, the Danish Energy Authority followed the consent procedures for offshore wind, with approval given based on a project's location, the results of an environmental impact assessment and plans for decommissioning. Denmark's system also allows for grid access.

D. Australia

In Australia, wave and tidal project developers can obtain consent to use and develop Crown lands under the Coastal Management Act (CMA). However, the process is imperfect.[21] First, the consents available under the CMA are subject to a company's ability to define a specific location for a specific unit. But most companies would prefer a consent that covers a broader area to allow for additional exploratory activities to identify the optimal location for the units. Second, the CMA is administered by different states, and there is much uncertainty at the departmental level.

Despite barriers, Carnegie successfully obtained a consent for its CETO I wave project prototype.[22] According to the PB Power Report (previous footnote), the project was subject to environmental review including impacts on marine flora and fauna observed at the site. However, it was also recommended that the developers conduct further studies to support project expansion, including studies of shoreline, bird and marine mammals, subsea and terrestrial acoustic surveys and wave monitoring ahead of and behind units. The developer also worked with many different stakeholder groups, and consulted with the State Government of Western Australia, the Department of Land Administration, Sustainable Energy Development Office, Fremantle Port Authority and Yachting Association of Western Australia for approvals for deployment.

[16] The UK declared a Renewable Energy Zone (REZ) in 2004. The REZ extends up to 200 nautical miles form shore and within the REZ, the UK has claimed exclusive rights to production of energy from wave and wind. *See* Section 84, Energy Act (UK) 2004.

[17] *See* Crown Estates Website, http://www.thecrownestate.co.uk/our_portfolio/marine/wave-tidal/application_process.htm

[18] BWEA Report (October 2009).

[19] *See* International Energy Agency, Global Renewable Energy: Policies and Measures database, http://www.iea.org/textbase/pm/?mode=re&id=4249&action=detail.

[20] *See* Wave Energy Centre Paper, Uppsala (September 7-10, 2009).

[21] Transcript, Environment and Natural Resources Committee, September 29, 2009.

[22] PB Power Report on CETO Technology, www.ceto.com.au/ceto-technology/pdf/pb-report-full.pdf (2007), (describing permit process).

E. New Zealand

In New Zealand, developers must obtain authorization for a project under the Resource Management Act (RMA). Regional councils and territorial authorities issue the required consents. All applications for a consent must include an Assessment of Environmental Effects (AEE) of likely project effects and mitigation strategies.[23]

In September 2009, the RMA was amended, largely to expedite and improve the resource consent process.[24] Changes include:

- Deterring frivolous, vexatious and anti-competitive objections that can add tens of thousands of dollars to consent applicants
- Streamlining processes for projects of national significance
- Creating an Environmental Protection Authority
- Improving plan development and plan change processes
- Improved resource consent processes
- Streamlined decision making
- Strengthening compliance by increasing penalties and proving for a wider range of enforcement
- Improvements to national instruments[25]

In 2008, two projects received approval under the former version of the RMA. Consents were issued to Neptune Power Limited by Greater Wellington Regional Council allowing it to deploy a 1 MW prototype tidal turbine in the Cook Strait. The environmental review for the Cook Strait Neptune Project examined impacts on marine mammals and whales, sedimentation, visual impacts, and navigation.[26] Consents were also issued to Crest Energy Kaipara Limited by Northland Regional Council for a 200 MW tidal project but these were immediately appealed by four groups, including Crest Energy itself (which objected to some of the consent conditions). The appeals were heard by the Environment Court in June 2009 and an interim decision published in late December 2009 indicates that the judge is minded to grant consents subject to conditions and an approved environmental monitoring plan.

[23] Wikipedia, "New Zealand Resource Management Act", http://en.wikipedia.org/wiki/Resource_consent#Plan_classificationshttp://en.wikipedia.org/wiki/Resource_consent#Plan_classifications

[24] *See* http://www.scoop.co.nz/stories/PA0909/S00123.htm (summary of RMA amendments).

[25] *See* http://www.scoop.co.nz/stories/PA0909/S00123.htm

[26] *Development of Marine Energy in New Zealand*, Power Projects Limited (June 30, 2008).

II. Regulatory Trends and Challenges for Marine Renewables

Having described the regulatory regime for licensing marine renewables in various locations in Part I, it is now possible to identify options for addressing problems and discuss future regulatory trends.

A. The Challenge: Deploying Demonstration and Early-Stage Projects

Advancement of the marine renewables industry depends on projects getting into the water so that developers can observe operation and impacts in real world conditions. Up until recently, many pilot projects have been subject to crippling environmental review disproportionate to predicted impacts, which increases the costs and delays associated with deployment.

1. Pilot Licensing Programs: A special "pilot project" authorization might cure this problem. In the U.S., FERC's pilot license process takes one year by replacing extensive environmental review up front with rigorous post-deployment monitoring. Meanwhile, the short term of the pilot license (five years) and application of principles of adaptive management (whereby developers must modify or cease project operation to address any observed adverse impacts) ensure adequate environmental protection. Unfortunately, the FERC pilot license program is still slow to reach its intended one year process goal since some regulatory agencies are requesting two years worth of data collection, thereby extending the one year process.

2. One-Stop Shopping: A streamlined, one-stop shopping process can also reduce licensing costs and delays. Some of the countries discussed – such as the UK or Canada (Ontario) have attempted to create a one-stop shopping approach to licensing. For example, in the UK, smaller projects are sited by the MMO, which helps with coordination, while Ontario's Renewable Energy Facilitation Office does the same. One-stop shopping reduces developer costs and cuts down on the complexity of permitting. Moreover, a one-stop approach puts one agency in the lead, and forces the others to cooperate. Unfortunately, in the U.S., one-stop shopping would require additional legislation to give the lead agency jurisdiction over other federal agencies. Moreover, without set deadlines, even a one stop process can be lengthy. But one-stop shopping apparently worked well for Denmark's offshore wind program and certainly deserves additional discussion inasmuch as the process could assist in siting marine renewables.

3. Test Centers and Pre-Screened Test Sites A third option for expediting deployment of pilot projects is creation of pre-screened test centers or sites. Though projects located in test sites may require additional environmental review, it is generally less extensive because the sites have been pre-screened. Test sites are also connected to the grid, so that developers can potentially sell power and earn revenues to offset development costs. Portugals's Pilot Zone is one example of a test site, as is the European Marine Energy Center (EMEC) in Scotland (for smaller projects) and the U.K.'s anticipated Wave Hub (http://www.wavehub.co.uk/) (for larger projects). In Ireland, the Galway Bay test facility is used for smaller devices in a less robust wave environment protected by the bay and Irish authorities have started developing a larger open ocean test facility. The Galway Bay facility benefits greatly from a collaboration with IBM and its SmartBay program, which has installed sensors throughout the Bay, which can measure sedimentation transport, turbine efficiencies, environmental impacts, fish and marine mammal behavior, and data for other industries and sea uses.

Test centers will play an important role in the marine renewables industry since they allow for expeditious deployment of demonstration and smaller projects. Even when marine renewables projects outgrow the capacity of the test center, because they provide a readily accessible site that will support ongoing innovation.

B. The Challenge: Moving Beyond Pilot Projects to Larger Projects and a Marine Renewables Industry

Once marine renewables move past the pilot phase to commercial operation, it will be necessary to explore ways to facilitate deployment on a systemic, rather than case by case basis. Strategic environmental assessments (SEA) and marine spatial planning (MSP) offer two options.

1. Lack of data on impacts

The SEA is a legally enforced assessment procedure required by Directive 2001/42/EC (known as the SEA Directive). The SEA Directive aims at introducing systematic assessment of the environmental effects of strategic land use related plans and programs. Both Scotland and Northern Ireland are preparing SEAs that will include marine renewables. Though the UK has been unable to perform an SEA for marine renewables for want of data, it will likely prepare one for prior to siting of larger arrays.

The U.S. has a similar concept to the SEA, known as a programmatic environmental impact statement (PEIS). In December 2007, MMS released a PEIS for development of alternative energy on the Outer Continental Shelf which mentioned marine renewables, though also noted that these technologies were not likely to be deployed for another five to eight years.[27]

2. Marine Spatial Planning

Many countries are exploring ways to manage competing uses in oceans through Marine Spatial Planning (MSP). The European Union (EU) has directives which require an examination of MSP issues, while the Obama Administration just released a draft report endorsing the adoption of MSP in U.S. waters up through the limit of the Exclusive Economic Zone (EEZ). Finally, a cursory review of the UK's Marine and Coastal Access Bill suggests that it adopts a version of marine spatial planning by allowing for creation of marine conservation zones.

Marine spatial planning can assist marine renewables by creating a system to deal with overlapping uses and competing claims. In addition, data collected using the MSP process can inform developers' siting decisions and thereby speed the license process.

Despite potential benefits, some developers in the United States remain wary of MSP, fearing that it might put off limits areas with prime wave or tidal power, which could constrain growth of the industry. In addition, there is concern about "zoning" the ocean without adequate data, or putting a moratorium on existing development while MSP is implemented. Whether MSP will help or hinder the marine renewables industry, at least in the short term, is a topic that will certainly generate much discussion in the year ahead.

[27] *See* MMS PEIS at http://ocsenergy.anl.gov/documents/index.cfm

The Standardization of Marine Renewable Energy Conversion Systems

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Summary
Wave, tidal and water current energy conversion systems are at the early stages of development with only a few technologies approaching full-scale commercial deployment. There are over 100 prototype technologies that are being developed world-wide to harness the potential and kinetic energy produced from waves, tidal and water currents. The resource opportunity for these technologies is substantial with energy estimates ranging between 8,000-80,000 TWh/yr for ocean waves and greater than 800 TWh/year for marine currents. Whilst the opportunity is enormous, there remain significant challenges facing this emerging industry. The development of well designed standards will assist in mitigating the technical and financial risks to move this technology into the commercial market space. This paper will discuss the role that international standards will play within this industry and the activities of IEC/TC 114, a committee mandated to develop marine energy standards.

Introduction
In comparison to other more established renewable energy technologies, there has been only modest investment in marine energy. Although there has been on-going research in this field for the last 30 years, technologies to harness the energy from waves, tidal and water currents are still at early stages of development. More focused attention has been given to this technology in the last few years, as countries explore alternative options to increase the amount of renewable energy in their power production mix, to reduce emissions affecting climate change, and to seek regional solutions to meet rising energy demands.

Today, the marine energy industry is characterized by a high number of prototype technologies with the first entering the commercial-deployment stage. The first commercial-scale multiple-unit array installation occurred in 2008. There is continued interest from governments and utilities wanting to see wave and tidal current energy as a viable source of electrical power, capable of being connected to the grid and contributing to the overall renewable energy supply in their respective countries.

With the diversity in configurations of the various technologies, particularly for wave energy devices where several power take-off systems exist, it becomes difficult to assess and compare the performance of one technology versus another. These variations may be a result of differences in technology but can also be attributed to methods in which technologies are being tested. For instance, two tidal turbines can have very different energy conversion efficiencies, but without standardized testing methodologies it is unknown which of the technologies is actually more efficient. Figures 1 and 2 illustrate two types of tidal energy converters.

A report, prepared for the International Energy Agency's Ocean Energy Systems Implementing Agreement (OES-IA) in 2006, noted that the absence of technical standards was one of the main barriers restricting the development of ocean energy technologies [1]. Furthermore, the lack of internationally recognized standards for development, testing and measurement has a negative effect on the credibility of the performance stated by technology developers. This becomes a very critical problem when developers are searching for investors that have a multitude of technologies from which they can choose to invest. Standards can provide investor confidence that a return on their investment, within a pre-determined level of uncertainty, will be achieved.

While developing national standards provides a foundation for technology comparisons, experience has shown that international standards offer industries greater technology mobility. Meeting international standards gives technology developers access to a global market. For instance, if a manufacturer were to build products conforming to various national standards, it would quickly lose the economies of scale having to produce products that conform to individual country standards requirements. Far from becoming trade barriers, standards promote international trade [2].

Figure 1. Open-centre, horizontal axis tidal current turbine (Courtesy: OpenHydro)

Figure 2. Vertical axis tidal current turbine (Courtesy: Ponte di Archimede International)

With this in mind and the recognition of a flourishing marine energy industry – with the potential for a significant global impact, the International Electrotechnical Commission (IEC), the organization that leads the standardization of electrotechnical equipment, established a technical committee to address the standardization of marine energy conversion systems (IEC/TC 114). This committee was formed in the fall of 2007 with the United Kingdom holding the Secretariat and Canada as Chair. The IEC has been establishing standards for over 100 years and is also the responsible body for international standards for other renewable energy technologies such as wind turbines, hydraulic turbines and fuel cell technologies.

In parallel to the activities of IEC/TC114, the development of standards for marine energy converters has been occurring at a more national and regional level. Most notable are the standards and guidelines that have been produced by the European Marine Energy Centre (EMEC) in the United Kingdom. A suite of thirteen documents have been produced by a working group with individuals representing technology developers, regulators, academia, utilities and project developers [3]. In April 2008, a project entitled *Equitable Testing and Evaluation of Marine Energy Extraction Device in Terms of Performance, Cost and Environmental Impacts* (EquiMar) was launched with 23 partners from 11 European countries. Funded by the European Commission, EquiMar will deliver a suite of protocols for the equitable evaluation of marine energy converters (based on tidal and wave energy) [4]. Close collaboration with these national and regional organizations will be important as IEC/TC 114 begins to develop international standards.

Innovation and the Role for Standards

Concerns have been raised that while marine energy technologies are at an early stage of maturity, early development of standards may stifle technical innovations. This risk can be mitigated by the development of 'performance-based' standards rather than 'design' or 'prescriptive' standards. The difference between these forms of standards is that performance-based standards focus on the behaviour of the object or its purpose while prescriptive standards generally specify dimensions and materials of the technology being standardized. For obvious reasons, performance-based standards provide more flexibility to technology developers without comprising safety issues.

The standards produced by IEC/TC 114 will be performance-based to provide the necessary guidance required to produce a product without limiting innovation within the industry. Moreover, in recognition of the embryonic state of technologies, standards currently being produced by the committee are Technical Specifications (TSs). Technical Specifications are used for pre-standardization purposes when the subject matter is still under technical development [5]. They are not considered International Standards, but serve as prospective standards for provisional application [6]. The review of the TS is required every 3 years, at a minimum, where it can then be withdrawn or further converted into an International Standard. This step aims to ensure that the specifications do not prohibit future technological innovation and that they remain current with state-of-art technology.

Independent of the industry, standards are critical in moving technologies forward by providing concise guidelines for device developers, manufacturers, regulators and users. They also serve to promote safety, reliability, and efficiency within an industry that relies on engineering components or equipment.

On the Path to Standardization

The objective of IEC/TC 114 is to prepare international standards for marine energy conversion systems. The primary focus of the committee is to address standards relevant to the conversion of wave, tidal and other water current energy into electrical energy. Other conversion methods relevant to electricity production from a marine environment (e.g. Ocean Thermal Energy Conversion (OTEC)) will be included within the scope of IEC/TC 114, but addressed as a secondary priority. Mature tidal power technologies, such as tidal barrage or dam installations, have been specifically excluded from the scope of this committee. This exception is explicitly stated as tidal turbines and the civil infrastructure surrounding these forms of ocean energy extraction are covered by IEC/TC 4, a committee that addresses standards relating to hydraulic turbines. As IEC/TC 4 focuses on hydraulic rotating machinery and associated equipment related to hydropower development [7], tidal power/barrages fall under the suite of standards offered by this committee. Technologies extracting the kinetic energy from rivers, also known as in-river or hydrokinetic, are included in the remit of IEC/TC 114, because of their similarity to technologies developed for tidal current applications.

IEC/TC 114 will produce standards that address diverse subjects, such as system definition, performance measurements, resource characterization and assessment, design and safety requirements, power quality, manufacturing and factory testing and the evaluation and the mitigation of environmental impacts.

The Committee: Its Structure and Work Programme

An IEC/TC consists of National Committees (NCs) who are members of the IEC and have a particular interest in a subject matter. Each NC represents its nation's electrotechnical interests and can consist of manufacturers, consumers and users, government agencies, professional societies and trade associations and standards developers. In some countries, national committees are public or private sector only, while others are a combination of both.

Today, IEC/TC 114 has fifteen NCs that are participating members of the committee. Participating members must actively vote on documents, attend and contribute to plenary meetings, and nominate experts to each working group and project team that formulate the work programme of the committee. National committees have discretion as to which activities they choose to take part in. There are also four observer national committees, who are interested in keeping abreast of the activities involved in the standardization of marine energy, but do not take an active role in the committee's activities.

To allow for a formal collaboration with other organizations pertinent to the TC's subject matter, IEC encourages the implementation of liaisons. To this end, IEC/TC 114 has established formal liaisons with the IEC/TC 4 and IEC/TC 88, a committee that develops standards for wind turbines. In addition, liaisons have been formalized with the IEA's OES Implement Agreement as well as EquiMar. These liaisons allow IEC/TC 114 to exchange basic documents with these organizations and allow for observers to follow the work of the committee or vice-versa. Liaison organizations do not possess the right to vote but they can contribute to and participate in working groups or project teams. These liaisons have already been valuable to IEC/TC 114, as experience from more mature committees has provided insight to the work programme of our committee.

Standards produced by IEC/TC 114 are denoted by the 62600 series, a number assigned by the IEC. To manage complexity regarding the annotation of the various standards being produced by this committee, a numbering system or nomenclature has been devised. Standards produced with a single digit suffix (i.e. 62600-1, 2, 3, etc.) will address issues that focus on more than one type of energy conversion system (i.e. wave and tidal energy). The dash 100 series (i.e. 62600-100, 101, etc.) will address issues particular to wave energy conversion while the dash 200 (i.e. 62600-200, 201, etc.) will be specific to tidal energy conversion. The rest of the centennial numbers, such as 300s and 400s, will be left open to allow for flexibility to address other types of technology standards that may be included as part of the future scope of this committee. For example, the 62600-300 series could potentially address standards that are specific to the conversion of water current energy into electricity.

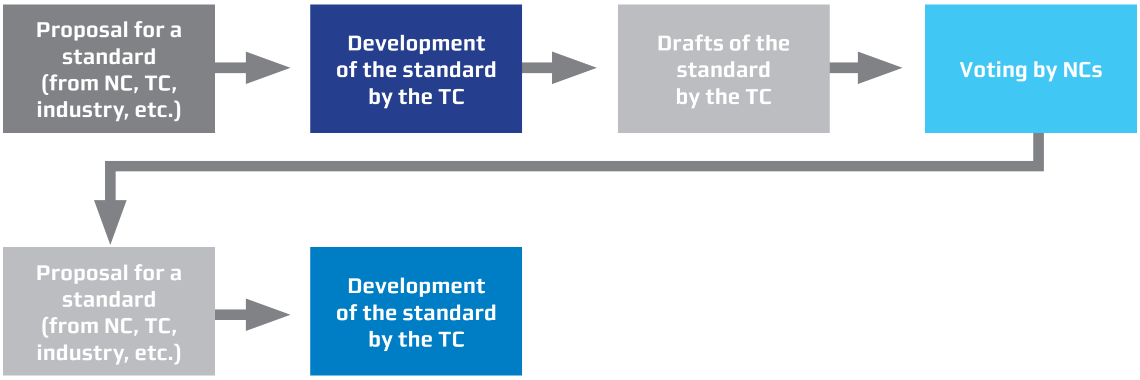

Figure 3. Standards Development Process

IEC/TC 114 is currently developing five technical specifications, which have been identified as key priorities for the first suite of standards to be delivered. Discussions remain underway on other possible technical specifications such as moorings and tank-testing. Additional standards will be initiated, based on interest and availability of experts, taking into consideration overall industry requirements as well as the sustainability of the committee.

The five technical specifications are discussed in more detail below. The IEC standards development process is illustrated in Figure 3. It is worthwhile mentioning that these documents take, at a minimum, three years to reach publication.

Terminology for Marine Energy (IEC TS 62600-1)

This TS defines terms related to marine energy converters and will provide uniform terminology in the form of definitions as they relate to wave, tidal and other water current energy converters. This specification will serve as a resource for the working groups and project teams as well as users. The establishment of defined terms early in the standard development process will ensure that uniform terminology is being applied to all future standards developed by this committee. Consistency is essential to remove any potential confusion related to existing multiple meanings for terms currently used within this industry. [8]

Design Requirements for Marine Energy Converters (IEC TS 62600-2)

This TS provides the essential design requirements to ensure the engineering integrity of wave, tidal and other water current energy converters for a specific design life. Its purpose is to provide an appropriate level of protection against damage from all hazards that may lead to failure of the primary structure (e.g. the collective system comprising the structural body, foundation, mooring and anchors, piles device buoyancy, and attachments). This specification will include requirements for subsystems of wave, tidal and other water current converters such as control and protection mechanisms, electrical systems, mechanical systems and mooring systems only as they pertain to the structural viability of the device in an open water site. [9]

Wave and Tidal Energy Resource Characterization and Assessment (IEC TS 62600-3)

This TS will provide uniform methodologies for the consistent and accurate characterization and assessment of both wave and tidal energy resources. This TS will enable marine energy project developers to characterize the wave/tidal resource and assess the potential of sites for deployment. It will enable the comparison of resources at different sites for both wave and tidal energy projects, a requirement that project developers will have and which device developers will be concerned to meet. This specification is intended to be applied to national, regional, areal and site-specific scales to enable a high-level screening as well as site-specific evaluations. Figure 4 provides a graphical representation of the densities available for tidal power.[10]

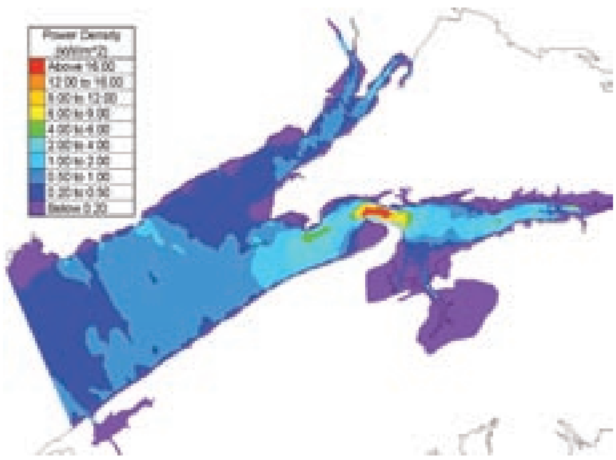

Figure 4. Tidal current power density for the Bay of Fundy, Canada (Courtesy: National Research Council)

Figure 5. Oscillating water column (Courtesy: Oceanlinx)

Figure 6. Oscillating body (Courtesy: Pelamis Wave Power)

Performance Assessment of Wave Energy Converters (IEC TS 62600-100)

This TS establishes the general principals for assessing the power production performance of wave energy converters (WECs) when deployed in the open sea. The TS is applicable to WECs which generate electricity using the wind-generated waves in order to deliver that electricity to an onshore grid by means of a cable connection. It is applicable to floating WECs both compliantly moored and taut-moored, and bottom-moored WECs. It is not intended to apply to tank testing or test basins. WECs have various configurations as shown in Figures 5 and 6.

Performance assessment will ensure that that there is an agreed methodology for the measurement of the power output of a WEC in a range of sea states, as well as provide a framework for the reporting of the results of these measurements. It will also enable the estimation of an annual energy production of a WEC at a prospective site where there is wave power resource information of sufficient detail and quality. [11]

Performance Assessment of Tidal Energy Converters (IEC TS 62600-200)

This TS establishes the general principles for assessing the power production performance of tidal energy converters (TECs) when deployed in open seas. It is applicable to TECs that generate electricity using the action of the tide in order to deliver electricity to the onshore grid by means of a cable connection. It is applicable to both floating and bottom mounted TECs. It is not intended to apply to testing in enclosed flumes or rivers. This specification will enable the performance of devices to be effectively validated, and consequently enable government, industry and the finance/investment community to form soundly based judgements of the commercial prospects of the technologies being demonstrated. Device performance will be characterized by using (but not limited to) a measured power curve, measured annual energy production and a continuous record of operational status. [12]

Conclusion

History has shown that companies involved in standards are more competitive and better equipped to meet market demands for new technologies [2]. Developing standards is a long-term investment that requires the collaboration of developers, manufacturers, regulators, international organizations and experts. As the industry is in its infancy, it is challenged by the lack of available resources, both in human and financial capital, to support the development of standards. It is apparent that a country that is interested in developing a marine energy market and technology capacity must take part in this effort, providing a solid foundation for technologies with a superior performance that are cost-competitive and reliable.

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[9] IEC TS 62600-2. Ed. 1. Design of Marine Energy Conversion Systems. (to be published)

[10] IEC TS 62600-3. Ed.1 Wave and Tidal Energy Resource Characterization and Assessment (to be published)

[11] IEC TS 62600-100 Ed. 1. The Assessment of Performance of Wave Energy Converters in Open Sea (to be published)

[12] IEC TS 62600-200 Ed. 1. Performance of Tidal Energy Converters (To be published)

5. National Activities

An overview of national activities and governmental initiatives to implement ocean energy in each OES-IA country member is provided by the respective contracting party in this chapter. Representatives and national experts from other countries also provided information on their relevant national activities.

MEMBER COUNTRIES

PORTUGAL

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Research and development continued being focused on (i) oscillating water column (OWC) plants, namely the improvement of the operating conditions of the Pico OWC plant that first entered into service in 1999, and also development of equipment (turbines) for this technology; (ii) one– and two bodies floating devices. Development of resource assessment methods continued, namely using remote-sensed satellite ASAR data. A growing interest by various companies led to the establishment of protocols, and in some cases already collaboration, with developers from different countries having in view the construction deployment and testing of wave energy converters (WECs) in the country, as a step for establishing an industrial and services cluster for wave energy utilization technologies.

Ocean Energy Policy

At the end of 2008, through Decree-Law 238/2008 (15 December) the government had appointed REN – Redes Energéticas Nacionais (National Energy Networks), S.G.P.S., S.A. to create a company dedicated to manage the Wave Energy Pilot Zone. In 2009 steps were taken having in view to establish such a contract between the government and REN. Probably due to the change of government in the last trimester of the year, this contract was not signed, however.

Research and Development

Research and development activity on wave energy utilization was performed at **Instituto Superior Técnico** (**IST**, the School of Engineering of Technical University of Lisbon) in close cooperation with **LNEG** (National Laboratory of Energy and Geology, Ministry of Economy and Innovation).

Special attention has been devoted at both institutions to modelling, optimization and control of offshore WECs, especially heaving one-body and two-body devices. Also object of theoretical modelling was the dynamics of moorings. This included the design of the spread mooring system for an offshore prototype (work done under contract) and also the mooring dynamics of arrays of inter-connected floating converters. The non-linear analysis of motions and mooring forces in single devices and in arrays is being carried on.

Model testing of a bottom-hinged WEC has been performed, under contract, in the 28m 12m irregular wave tank of University of Porto (joint work with University of Porto).

A self-rectifying air turbine was designed, and is being model-tested in laboratory, to be supplied and installed on the one-quarter-scale prototype of the OEbuoy floating OWC plant being tested in Galway Bay, Ireland (EC CORES project, joint work with Kymaner).

In the field of tidal energy, theoretical and numerical work has been carried out on the hydrodynamic modelling of horizontal axis marine current turbines. A Boundary Element Method (BEM) code has been used to compute the flow on a model scale marine current turbine in uniform axial and yawed inflow conditions and the results compared with published data from cavitation tunnel and towing tank tests.

IST is a partner of Wavetrain 2 – People Initial Training Network Programme of the European Union. Use of more advanced data for wave energy resource characterization has been going on at LNEG using new types of remote sensed wave data (directional spectra obtained from SAR/ASAR measurements). Work on the joint assessment of offshore wind and wave energy resources was pursued within the EC FP6 Coordination Action Prediction of Waves, Wakes and Offshore Wind (POW´WOW), being LNEG the coordinator of Offshore Data Task. Using a comprehensive Geographical Information System (GIS),database (PEMAP – Potential of Marine Energies in Portugal) developed at LNEG for site selection of wave energy farms, continued as a means to provide authoritative guidance for installation of wave devices in the country.

Wave Energy Centre (WavEC) is a private non-profit association created in 2003. WavEC's objective is to promote and support the cooperation between companies, research and financing institutions and other entities, aiming at the development, promotion, support for commercialisation and transfer to the industry of wave energy technologies. The Centre has 15 associates including companies from the energy, industry and services sectors and three R&D institutions. Main research activities by WavEC in 2009 were connected to 3 European funded projects:

- EquiMar – *Equitable Testing and Evaluation of Marine Energy Extraction Devices in Terms of Performance, Cost and Environmental Impact* (FP7-RTD); WavEC leads the environmental research component;
- Wavetrain2 – *People Initial Training Network Programme of the European Union*; project coordinated by WavEC;
- CORES – *Components for Ocean Renewable Energy Systems* (FP7-RTD) – WavEC is responsible for developing the numerical wave-to-wire model of a floating OWC system.

Kymaner is a small-medium enterprise (SME) keeping its focus on the demonstration of the validity of the Oscillating Water Column approach for the exploitation of wave energy. Several initiatives were started or pursued in the course of 2009, some of which will proceed into the coming year, namely:

- The Pico plant is now fully operational after the development of an anti-vibration solution supplied by Kymaner, enabling the turbo-generator group to perform at full rated speed for the first time since the original installation in 1999; further, WavEC assigned Kymaner for generic plant maintenance, including the elaboration of a preventive maintenance plan which makes it possible for the plant to be operated regularly and consistently deliver energy to the Pico island grid.
- Designed for installation in OWC offshore platforms, Kymaner produced an efficient impulse turbine of a new concept, suited for a wide power range, to be tested in the Ocean Energy scale hull during 2010, as part of the EC CORES Project. Both suited for reduced scale testing of OWC floating platforms and breakwater wave plants, this company has started the development of an innovative Wells turbine, designed for cost and compactness. This new design shall start aerodynamic testing in 2010 and is expected to be a breakthrough in this type of technology, for the lower unit power range.

Martifer Energy Systems, a business unit from the Martifer Group with different activities in the renewable energies field including manufacturing of components and services of engineering, procurement, construction and O&M of onshore wind installations has significant R&D activities in ocean wave energy and concentrated solar power (CSP). Conscientious of the huge potential of wave energy and of the opportunity of developing an alternative technological solution to transform wave energy in electrical energy,

Sketch of the Martifer offshore Flow device

Martifer started developing in-house its own offshore wave energy technology (Flow system) with some technical support from several Portuguese R&D institutions with relevant expertise for this type of project. After performing the main activities related with the offshore device and acquiring a ship-yard in order to construct a full scale prototype and perform the first tests at sea, due to the significant amount of financing need for the construction and testing of the prototype and also due to present economic environment, the project funding strategy was re-defined during 2009. The main activities during this year were related to the review of the device design in order to identify the main opportunities for significant cost-reduction and at the same time Martifer is also searching for partnerships to perform the following phases of the development of the technology.

EFACEC: Within its mission of continuous presence in the renewable energies value chain, namely supporting the promotion and development of renewable energies in particular wave energy, this company continued to actively participate in the Pico OWC plant project. Support was provided for maintenance and upgrade having in view achieving permanent operation.

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

Technology Demonstration

The Pico OWC

The wave energy pilot plant on the Island of Pico,Azores, based on the oscillating water column (OWC) technology, was conceived in the nineties by a mainly Portuguese consortium under the coordination of IST (Instituto Superior Técnico). The plant was funded by the European Commission, the Portuguese state, EDP and EDA (Azores utility). After initial commissioning trials in 1999, accidents and lack of resources led to degradation of the first grid-connected European wave energy pilot plant, without having operated over significant periods.

The 400kW plant was owned until 2003/04 by EDA, who transferred the responsibility to the **Wave Energy Centre (WavEC).** Almost simultaneously, a recovery project was initiated involving Portuguese public funds (600k€) and private investment from WavEC associates of the same order of magnitude.

The plant was successfully refurbished and has operated on a regular basis since late 2006, with strong limitations due to original design and installation errors. However, the conditions have consistently been improved with the minimalist resources of WavEC, and with the technical collaboration of the Portuguese company Kymaner it is now possible to run the OWC at its rated speed.

The operational experience acquired by WavEC and Kymaner contributed to accumulate the essential know-how for the creation of a national competence centre for OWC technology, which is why WavEC continues to insist in maintaining and improving the conditions of Pico OWC. Consuming large parts of its own financial means, WavEC invested approximately 115k€ into the project, and yielded several noteworthy milestones, in particular its continuous

Pico Power Plant, Azores

operation longer than 24 h (48 h in spring), operation at full rated speed (up to 1500 rpm) in September, and 100h continuous operation in early October.

Demonstration EU-funded projects

Three wave energy technologies were granted EU funding in 2009 for demonstration of full-scale grid connected devices: WaveRoller (AW-Energy), Powerbuoy (OPT) and Wavebob (Wavebob Ltd). The Wave Energy Centre is formal partner of the first two projects, with a key role in the monitoring activities, and further significant involvement in the third project is also anticipated. Whereas two projects have started by late 2009, the other one starts early 2010.
Further, the Wave Energy Centre has intensified its effort in the Waveplam project (www.waveplam.eu), an Intelligent Energy Europe–funded action to raise awareness and remove barriers for the future wave energy implementation.

EDP, Energias de Portugal, S.A.

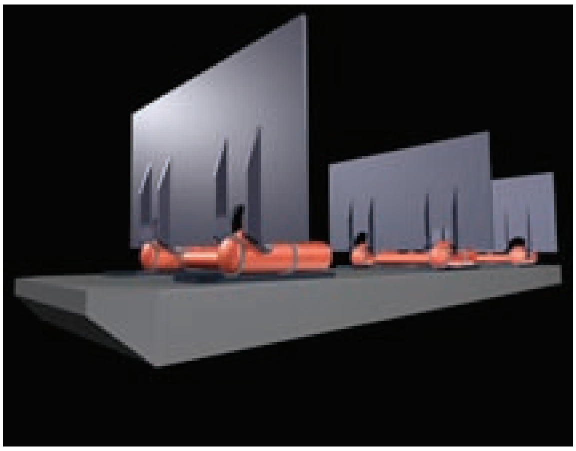
EDP has undertaken a number of actions in the area of ocean renewable electricity generation, namely in wave energy and deep-offshore wind technologies. EDP's strategy in this domain includes:

- Participation in the technology development phase (in partnership with technology developers) capturing growth options for the future.
- Development of technological and scientific competences in the Portuguese research community.
- Development of an industrial and services cluster in the ocean energy area (offshore wind and wave energy) in Portugal.
- Implementation of an open technology strategy, sharing risks and costs, through the development of several demonstration projects.
- EDP has taken several specific steps, namely:
- Acquisition of the Aguçadoura site, in partnership with EFACEC.
- Has secured an acquisition option over the following generation of Pelamis wave energy converter.
- EDP and EFACEC have initiated a collaboration platform named "Ondas de Portugal" (Waves of Portugal) aiming at the development of demonstration projects in the wave energy sector and establishing the basis for a future ocean energy cluster in Portugal.
- In partnership with EFACEC, Martifer, GALP Energia, Wave Energy Centre and Universidade de Aveiro, EDP is developing the Institute of Offshore Energy (IEO). IEO will provide overall support to the development of technologies and projects in the ocean energy area.

ENEÓLICA, Energias Renováveis e Ambiente Ltd

This company, integrating the Portuguese Group Lena, has been carrying out actions with two wave energy converters. The first is the Wave Roller (AW Energy, Finland); more recently contacts have been started with the British company Orecon.

- **WaveRoller:** Following the two series of tests in the sea since 2007 in Peniche (100km north of Lisbon) of Wave Roller units, detailed hydrodynamic simulations in model tank tests were pursued in 2009 jointly by IST and the Faculty of Engineering of Porto University (FEUP). After the approval of the demonstration project submitted to the European Commission for a demonstration of a full-scale unit in Peniche, this project started officially at the end of the year (middle November 2009). The majority of the WaveRoller demonstration unit will be constructed in Portugal. It is planned that the deployment will occur before the end of the summer of 2011.



Sketch of WaveRoller (courtesy: AW Energy, Finland)

- **Orecon:** Eneólica has signed an agreement with Orecon, a British company based in the South West of England that is the developer of the Multi Resonant Chamber (MRC) wave energy device that uses OWC principles. The objective of this MoU is to supply Eneólica with a 1.5 MW MRC wave energy unit after ORECON deploys the first full-scale device, which is expected to occur after 2011.

GWH

This company has become a partner of Oceanlinx, the Australian company that developed and built a full-scale nearshore OWC prototype.

GENERG

During 2009, Generg has entered into a consortium agreement with Wavebob Ltd, Vatenfall AB, Hydac System GMBH, Wedge Global SL and Germanischer Lloyd Industrial Services GmbH. The purpose of this consortium is the promotion of the "Standpoint" project, consisting in the deployment on 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. In the frame of the referred project, a Grant Agreement was closed between the European Commission and the consortium incorporated by Generg in the Seventh Framework Programme 7 (FP7) which assures a European Union financial contribution for the construction and deployment of the full-scale Wavebob device.

GALP ENERGIA

Following the actions initiated in 2007, GALP continued the studies to select one wave energy technology having in view its deployment and exploitation in Portugal. Starting with 20 technologies, a further analysis led to the selection of 10 technologies, which were benchmarked resulting in a short-list of 4 technologies. Visits to the selected developers were made. A visit to the Portuguese coast was carried out for pre-selecting appropriate site(s) for wave energy converters deployment. Contacts of commercial type have been underway in order to finalize a contract with the developer to be selected.

TECNEIRA, PROCME Group

This company has established strategic protocols with various developers from different countries and participated in more than one proposal of demonstration projects submitted to the European Commission calls, having in view the participation in the deployment and testing of wave energy converters in Portugal. This company has applied for a 3 MW license for deploying wave energy converters in the Peniche area (close to the Pilot Zone). In 2010, the company expects to start collaborating with a specific developer for the WEC deployment and testing in Portugal.

REN – National Energy Networks

REN has been appointed by the Government to be the manager of the Portuguese Wave Energy Pilot Zone. The Pilot Zone will be a large (320 km^2) area located about 120 km north of Lisbon, water-depth between 30 and 90m, to be used for the deployment of demonstration, pre-commercial and commercial wave energy plants and farms, the total maximum capacity being 250 MW. Plants licensing will be made by a one-stop-shop. REN has been preparing the contract to be established with the Government for the management of the Pilot Zone.

DENMARK

Kim Nielsen, Ramboll, Denmark

During 2009, Wave Star Energy A/S installed a 50 kW section prototype in the North Sea in Hanstholm. As a consequence, plans are being made to create a Danish Wave Energy Centre (DanWEC) for testing wave energy systems in Hanstholm as a next step, following small-scale experiments in the sheltered sea in Nissum Bredning (NB). Presently three different Danish concepts are installed in NB. Finally, the Lindø Offshore Renewables Centre (LORC) has been founded with the vision to establish a world-class R&D centre on future offshore renewable energy systems.

Ocean Energy Policy

Funding for wave energy projects in Denmark can be applied in competition with other renewable energy projects, through different national support programmes (see Table 5.1).

The EUDP 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 before becoming commercial 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 photovoltage, wave-energy and biogas. Grid connection is required and each project can define a "feed in tariff" as support for the project period.

The programmes cover all renewable energies. Typically wave energy receives less than 5 % of these funds. The Danish Council for Strategic Research and the Danish National Advanced Technology also cover non-energy projects.

Million EUR	2008	2009	2010*
EUDP	28	39	53
The Danish Council for Strategic Research	13	23	40
R&D (PSO) ForskEL & ForskVE	21	21	21
The Danish National Advanced Technology Foundation	1	1	2
Total	63	84	116

*Forecast
Table 5.1: Danish Government R&D Expenditure

Research and Development

In 2009 two new initiatives for wave energy development were taken:

- DANWEC, Danish test site for Wave Energy Conversion in Hanstholm.
- Lindø Offshore Renewables Centre, a science and development centre for offshore renewable energy.

The main Danish Universities and institutions active in ocean energy R&D projects are Aalborg University and the Danish Hydraulic Institute (DHI).

Technology Demonstration

The wave energy technology projects being developed in Denmark are described below (see also table 5.2):

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

Prototype section of the Wave Star converter

Floating Power plant

Floating Power Plant: Floating Power plant finished the first test at sea in 2009 at the sheltered sea outside Vindeb. This will be followed by a second test starting in spring 2010. In parallel with open sea testing, R&D work in wave flumes is being carried out.

Wave Dragon: Wave Dragon has been reinstalled in the scale test site 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.

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

Dexa: Dexa wave energy converter has been built in scale 1:10 and being tested in Nissum Bredning in 5 meter water depth. The device was installed in March 2009, the Power Take -Off (PTO) has been improved and presently it has been operating successfully for the last two months.

Leacon: A 1:10 scale model of the Leacon device has been built and installed with one electrical generator and one pneumatic damper for power dissipation. The device will be installed in the spring of 2010 in Nissum Bredning and join the Wave Dragon and the 1:10 scale Wave Star.

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

Project	Phase of development	Installed Power	Dimensions and weight	Public investment	Private investment
Wave Star	Prototype testing	2*25 kW= 50 kW	2 floats of D=5m 1000 ton structure	35 mio. DDK	60 mio. DDK
	1:10 Testing NB	5.5 kW	40 floats of D=1m		
Floating Power Plant	Prototype testing	140 kW	L 25m, B 37m h=6m, w= 300 ton	–	15 mio. DDK
Wave Dragon	scale prototype NB	20 kW	L= 33m, B=56m d=2.5m, w=237ton		
Waveplane	Prototype built not installed	2*100 kW= 200 kW	L=20m, B=18m, d=8m, w=110 ton	0	18 mio. DDK
Dexa	1:10 prototype testing NB	0,4 kW	L=7m, B=2.5m d=1m, w= 800 kg	0	1.7 mio DDK
Leacon	1:10 model ready to install	1 kW el 1 kW phn	L=11m B=24 w=2.2 ton	2.4 mio DDK	
Crestwing	Laboratory testing	-	-	0.5 Mio DDK	

Table 5.2: Ocean Energy Devices under Development in Denmark

UNITED KINGDOM

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

The UK Government made a number of marine energy related announcements in the UK Renewable Energy Strategy (www.decc.gov.uk) in July 2009, allocating up to an additional £60 million for a suite of measures which will accelerate the development and deployment of wave and tidal energy in the UK. These measures include: investments to expand and improve the UK's marine energy testing, development and demonstration infrastructure, the setting up of the new Marine Renewables Proving Fund (MRPF) that will provide up to £22 million of grant funding for the testing and demonstration of pre-commercial wave and tidal stream devices to accelerate the development of the leading and most promising marine devices towards commercialisation. The Government also announced it was developing a Marine Action Plan (covering wave, tidal range and tidal stream energy) in conjunction with the marine energy sector that is intended to be a practical guidance document that outlines the actions required by both private and public sectors to facilitate the development and deployment of marine energy technology. The Action Plan will cover key topics such as finance, planning and consenting, roadmapping of the technology and infrastructure.

Ocean Energy Policy

The UK Government made a number of marine energy related announcements in the UK Renewable Energy Strategy in July 2009, allocating up to an additional £60 million for a suite of measures which will accelerate the development and deployment of wave and tidal energy in the UK. These measures include £10 million investment in the New and Renewable Energy Centre in Northumbria, £8 million expansion of the European Marine Energy Centre in Orkney to provide additional wave and tidal berths and the creation of a nursery site, alongside the planned £9.51 million in Wave Hub in Cornwall. This will provide the UK with an unparalleled marine energy testing, development and demonstration infrastructure.

The **Marine Renewables Proving Fund (MRPF)**, administered by the Carbon Trust, will provide up to £22 million of grant funding for the testing and demonstration of pre-commercial wave and tidal stream devices. It aims to accelerate the leading and most promising marine devices towards the point where they can qualify for the Government's existing MRDF support scheme and, ultimately, be deployed at a commercial scale under the standard Renewables Obligation. The scheme will lead to faster progress in the marine energy sector and lower risk investment propositions for the private sector – driving the industry towards large scale deployment.

£10m of additional marine related investment will be made in the South West.

The Government also announced it will be working with the marine energy sector to develop a **Marine Action Plan**. The Marine Action Plan will provide the basis for considering the framework of support for the deployment of wave and tidal technology, including revenue support through the Renewables Obligation.

The Action Plan is intended to be a practical guidance document for both Industry and Government covering key topics such as finance, planning and consenting, roadmapping of the technology and infrastructure (including ports, grid, supply chain and skills) and acting as a spur for the sector by sending strong positive signals to the whole industry.

The Marine Action Plan will set out an agreed vision for the marine energy sector to 2030, with reference to 2020, and outline the actions required by both private and public sectors to facilitate the development and deployment of marine energy technology and fulfil the vision set out in the

UK Renewable Energy Strategy and Low Carbon Industrial Strategy. Covering wave, tidal range and tidal stream energy, the Action Plan will have a UK-wide focus while respecting the diversity of policy making powers under the Devolution Settlement.

The draft Marine Action Plan is expected to be published by Easter 2010 for public consultation and be a practical, working document which will be subject to revision over time.

The Government undertook a screening study in English and Welsh waters, covering wave, tidal stream and tidal range (outside of the Severn Estuary), to understand better the energy generation potential of marine energy devices and to understand better the realistic timescales of when multiple devices will be installed and commissioned. Should the screening study conclude that a **Strategic Environmental Assessment (SEA)** is required for English and Welsh waters, this work will help frame the development of a scoping report and a draft plan in terms of target energy generation capacity for future deployment of commercial multi device arrays, likely areas of development, and timescale.

The **Crown Estate** is expected to announce the allocation of leases for the wave and tidal programme in the Pentland Firth area by end of March 2010.

Severn Tidal Power Feasibility Study
The UK Government is currently carrying out a study looking at the feasibility of a tidal power scheme in the Severn Estuary. The aim of the study is to enable Government to decide (in the context of the UK's energy and climate change goals and the alternative options for achieving these) whether it could support a tidal power scheme and if so on what terms.

Five potential schemes (three barrages and two lagoons) are being considered and Government is also providing funding to bring forward the development of three schemes using embryonic technologies (which may offer the potential for getting power from the Estuary in an environmentally benign way). The decision on whether to support Severn tidal power, and if so what the preferred option may be, will be a question of the relative costs, benefits and impacts of a Severn tidal scheme compared to the other options for meeting the UK's energy challenges. A second public consultation will be held in 2010 before a final decision is taken.

Devolved Administrations:

- **Scotland**
  In August 2009 the **Marine Energy Roadmap** was published. This is an industry led view on Scotland's marine industry and its ambitions for 2020 and beyond. The key areas of consideration are finance, grid, planning/consents and infrastructure/supply chain. The roadmap sets out a number of recommendations in each area for actions that will support the industry in moving forward. A copy of the roadmap can be found at the following link: http://www.scotland.gov.uk/Publications/2009/08/14094700/0

  The **Marine Bill (Scotland)** was introduced in the Scottish Parliament in April 2009. The Bill will be creating a new legislative and management framework for the marine environment. **Marine Scotland** has been established as a Directorate of the Scottish Government as the lead marine management organisation in Scotland. Marine Scotland integrates core marine functions involving scientific research, compliance monitoring, policy and management of Scotland's seas.

The Scottish Government commissioned a **Marine Spatial Plan for the Pentland Firth and Orkney Waters** which is looking at the environmental challenges and potential future development and commercial opportunities. The Marine Spatial Plan will form a key part of the future management of the Pentland Firth and Orkney Waters. One of the key objectives will be to map areas of opportunity for the development of wave and tidal power. It will act as a planning tool for developers, regulators and existing users of the marine environment.

- **Northern Ireland**
  During 2009, the Department of Enterprise, Trade and Investment undertook a **strategic environmental assessment of its offshore renewable energy strategic action plan 2009-2020** to develop offshore wind and marine renewable in Northern Ireland waters www.offshorenergyni.co.uk/. Following public consultation in early 2010, the plans will be finalised and will enable The Crown Estate to launch a competitive call for projects in 2010-2011.

  The draft **Offshore Renewable Energy Strategic Action Plan 2009-2020** will contain a range of operational and legislative actions to support the development of offshore renewables in Northern Ireland waters.

Research and Development

The **Marine Renewables Proving Fund (MRPF),** administered by the Carbon Trust, will provide up to £22 million of grant funding for the testing and demonstration of pre-commercial wave and tidal stream devices.

The **Technology Strategy Board (TSB)** announced it will be providing up to £10 million for targeted support for 3-4 years collaborative projects through a new competition that will be launched in spring 2010. The TSB is consulting with the sector to develop the details.

The **Energy Technology Institute (ETI)** is also working with United Kingdom Energy Research Centre (**UKERC)** to use their technology roadmap as the basis for a marine strategy roadmap to inform future funding decisions. The ETI has also commissioned a technology benchmarking exercise that will be available shortly.

In 2009 the ETI also announced the funding of two wave and tidal energy projects. The **Performance Assessment of Wave and Tidal Array Systems project (PerAWaT),** led by Garrad Hassan, and including EDF Energy Ltd, E.ON AG, The University of Edinburgh, the University of Oxford, Queen's University Belfast and the University of Manchester, will develop a series of models to predict the performance of wave and tidal stream generator arrays. The **Reliable Data Acquisition Platform for Tidal project (ReDAPT),** which is being led by Rolls Royce and Tidal Generation Ltd, will install and test a 1 MW horizontal axis tidal turbine. The project will also develop analytical and environmental assessments and progress certification guidelines to increase public and industry confidence in tidal turbine technologies

Scotland

The Scottish Government is currently working with Scottish Enterprise (SE) and Highlands & Islands Enterprise to look into the possibilities of a new round of R&D support for marine renewables sector.

Northern Ireland

Queen's University of Belfast (QUB) and the Ulster University continue to undertake research into renewable technologies. In particular QUB has been involved for a considerable number of years in wave research –e.g. the recently announced Oyster development at the European Marine Energy Centre (EMEC).

Wales

The Assembly Government funded Low Carbon Research Institute 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. In addition, to support the progress of tidal projects in Wales, the Assembly has committed to;

- explore the exceptional international opportunities for Wales in marine energy in conjunction with International Business Wales,
- develop the skills agenda to ensure as much as possible of R&D and other activity is translated into company wealth generation, and;
- ensure exploitable energy innovations are eligible for new European Union (EU) Structural Funds support.

The Welsh Energy Research Centre (WERC) will focus on development and demonstration projects, to facilitate the rapid commercialisation and exploitation of the research carried out within the research institutes. WERC will be working with other research initiatives to make the best results possible, especially the Energy Technium in Pembrokeshire and Sustainable Technium at Baglan Port Talbot. The Energy Technium will be a key factor in large scale marine energy projects such as tidal stream and wave.

Technology Demonstration

Aquamarine Power Ltd

Aquamarine Power Limited successfully launched the world's largest working hydro-electric wave energy device to produce power, known as 'Oyster'. The Oyster demonstrator device, installed at EMEC, Orkney, has a capacity of 315KW. The Oyster 2 project is on track to install 2MW pods in 2011.

Voith Hydro Wavegen Ltd

In January 2009 Voith Hydro Wavegen (previously known as Wavegen) was granted consent to operate a wave farm with a maximum capacity of 4 MW off the Isle of Lewis. This is the largest consented wave electricity station in the world.

Marine Current Turbines

The Marine Current Turbines tidal stream project " SeaGen" was the world's first commercial scale tidal stream project to connect to a national grid with its 1.2MW twin turbines generating renewable electricity for around 1000 homes.

Wave Dragon Ltd

Commissioned in 2007, Wave Dragon's pre-commercial demonstrator off Milford Haven will be UK's first and largest offshore wave energy installation. The project will produce enough clean, green electricity each year to meet the annual demand of between 2,500 and 3,000 homes. This clean generation will offset the release of about 1,000 tonnes of carbon dioxide every year. The Milford Haven Wave Dragon pre-commercial demonstrator is a single floating slack moored wave energy converter with a rated capacity of 4-7MW. Wave Dragon Ltd has been working toward commercialisation of the device for 3 years.

Tidal Energy Ltd

Tidal Energy Ltd is developing the tidal stream energy device called DeltaStream. The 1.2MW device is scheduled to be deployed off Pembrokeshire, South West Wales, during October 2010 for a 12 month test period. The device will be grid connected via the local distribution network and will provide enough clean, green electricity each year to meet the annual demand of 1,000 homes.

JAPAN

Yasuyuki Ikegami, Institute of Ocean Energy, Saga University

Ocean Energy Policy

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). The main contents concern research and technology development for the implementation of methane hydrate and seafloor massive sulphide deposit (Roadmaps), however ocean energy is not mentioned.

The "Basic Plan on Ocean Policy" is based on the law "The Basic Act on Ocean Policy" and was launched in July 2007, in order to promote the utilization and development of ocean and preservation of the marine environment. The "Basic Plan on Ocean Policy" was settled by the Cabinet, in March 2008, as a guideline for ocean policy for the next 5 years. Twelve measures, in which the Government is going to engage, are incorporated in this plan, including development and commercialization of submarine resources such as methane hydrate and seafloor massive sulphide deposit. Concerning wave power and tidal power generation as Ocean Renewable Energy, the plan expresses that "While grasping international trends including those in countries where such generation has been put into practice, basic research for improving efficiency and economic potential should be promoted with due consideration to special features of seas around Japan".

Because of these situations, the national support system regarding Ocean Renewable Energy in Japan is considerably weak compared to other Renewable Energy. Especially in Japan, Ocean Renewable Energy is not included in the new sources of energy stated in the Law concerning special measures to promote the use of new energy (New Energy Law). Therefore applications for financial assistance for promoting practical use of ocean energy can still not be received.

However, in recent years, expectations for the implementation of Ocean Renewable Energy by Government, administrations and even private companies are higher. Although in a quite small scale compared to the Occident and other Asian regions, some projects have been demonstrated in specific areas in the ocean and large-scale plans have been announced. The Agency for Natural Resources and Energy of Ministry of Economy, Trade and Industry has enforced a basic survey of new energies to introduce and promote ocean energy.

Research and Development

Two wave energy devices are being investigated: a wave power generation system by gyroscopic effect (Max 45kW) and a wave power generation system based on electroactive polymer artificial muscle (EPAM).

Research on ocean current energy is done in connection between industry-academic-government to develop and implement a "loop type ocean current power generation system" (2 MW rated capacity), in which larger size of turbine blade is possible using Japanese original technology.

In July 2009, the Tokyo Metropolitan Government initiated the evaluation of the possibility of utilization of wave power generation and listed, as goals, the inclusion of wave power generation in the new energy law and further to identify and examine problems towards commercialization.

New Energy and Industrial Technology Development Organization (NEDO) of the Executive Agency, aiming to develop original and innovative technologies and contribute to improve technology utilizing ocean energy in Japan, started, in 2009, the programme "Advanced Research on Ocean Renewable Energy", in order to support the study and development of ocean energy for the first time. Three of the five projects included are: i) Study of Ocean Thermal Energy Conversion (OTEC) using ammonia/water mixtures as working fluid, ii) Wave power generation system by overtopping and iii) Ocean current power generation system using contra-rotating propeller system.

Technology Demonstration

Japanese companies, such as Mitsui Engineering & Shipbuilding Co., agreed to carry out the development plan of a demonstration wave power project using the Ocean Power Technologies (OPT) technology, and announced a 10 MW project to start soon.

IRELAND

Eoin Sweeney, Ocean Energy Development Unit

Implementation of Ireland's Ocean Energy Strategy accelerated in 2009. A Strategic Environmental Assessment process was initiated for Wave, Tidal and Offshore Wind development in all Irish coastal waters and legislation to establish a new planning system proceeded. Work continued on the establishment of a Phase 5 Wave test facility. A new funding mechanism for industry commenced and a range of projects are being supported. Further studies were commenced on the economics of ocean energy and supply-chain and infrastructure issues associated with the development of Ocean Energy projects.

Ocean Energy Policy

In 2006, the Marine Institute and Sustainable Energy Ireland prepared the 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 capability was enhanced and some funding was provided, from a variety of sources, to researchers and developers.
- Phase 2 (2008-2010) continues activities of Phase 1 and provides enhanced support for the demonstration of pre-commercial single devices. The results of this phase will be used to assess the commercial viability of the technology and the resulting industrial opportunities available to Ireland. A grid-connected test site will be developed during the period 2008-2010.
- 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 has now changed 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. €27m, to be administered by a new Ocean Energy Development Unit (OEDU), based in Sustainable Energy Ireland.

The 2009 the financial allocation covered:

- Support for Device Developers
- Enhancement of the test facilities at the Hydraulics and Maritime Research Centre, University College Cork
- Development of grid-connected test facilities
- Operation of the OEDU
- International Energy Agency (IEA) and commissioned studies

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

Other important initiatives include the undertaking of a Strategic Environmental Assessment (SEA) of Offshore Wind, Wave and Tidal Energy Development in all Irish waters. The SEA process began in October 2009. It will involve extensive public and stakeholder consultation and is expected to be completed in October 2010. In parallel, the OEDU is working with the relevant authorities to devise a streamlined system for licensing ocean energy developments. Under new legislation, to be passed before end-2009, planning functions in respect to marine renewables development are being located within the Department of the Environment and Local Government, will fall within the streamlined procedures of the Strategic Infrastructure Act and will provide for integrated processing of onshore and offshore planning issues.

Further developments include the completion of a study entitled 'A Review of Engineering and Specialist Support Requirements for the Ocean Energy Sector'. The study is intended to serve as a starting point for consideration about how the private and public sector can mobilise the delivery of the infrastructure and industry supply-chain capabilities that are necessary to enable the large-scale development of renewable energy resources. A further commissioned study is underway to measure the overall economic costs and benefits of a variety if scenarios for deployment of ocean energy and the implications for public sector finance and support.

Research and Development

An R&D funding scheme for industry-led projects in the field of wave and tidal technology has been launched. This 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 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.

During 2009, €4.3 million were committed, by OEDU to 12 industry-led projects with a total value of €10.6 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 is planned, with financial support from the Higher Education Authority.

University of Limerick has been actively pursuing the development of air turbines for use with oscillating water column devices. They have also secured long term funding under the Parsons Award scheme and intend to pursue ocean energy research activities.

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.

Technology Demonstration

Open Hydro: The Open Hydro tidal turbine is owned and developed by an Irish company based in Dublin with manufacturing facilities in Greenore, Co. Louth. The Open-Centre Turbine's simple design means that it can withstand harsh ocean tides, while having no impact on marine mammals since it has no oils which can leak, no exposed lade tips and a significant opening at its centre. A grid-connected turbine is currently being tested at the European Marine Energy Centre (EMEC) in the Orkney Islands. The company developed and utilised a purpose-built installation barge which was utilised for the 2nd generation device recently deployed in Nova Scotia, Canada. The company has won additional contracts to deploy devices in the Channel Islands, US and France.

Ocean Energy Buoy: The Ocean Energy Buoy (OE Buoy) is a floating oscillating water column device which generates power from compressed air which is created with each passing wave. The OE Buoy was optimised at 1:50 scale in Hydraulics and Maritime Research Institute (HMRC) before being tested at 1:15 scale in a large wave tank in Nantes. The current 1:4 scale machine was first installed in Galway Bay in December 2006 where maximum wave heights reached 8m during the winter period. The machine was successfully tested from December 2006 through to the summer of 2007 without a turbine in order to give comparison with previous tank test work. In September 2007 the OE Buoy was fitted with an air turbine and returned to test where it has performed successfully for over 2 years. Further turbine development work is underway and plans are proceeding for construction of a scale device.

Wavebob: The Wavebob is a point absorber device. The Wavebob has been tested at 1:50 and 1:20 scale before a decision to build a 1:4 scale machine was taken. A large scale prototype was installed in Galway Bay in 2006. The developers have an ongoing test programme of development at the test site. Some testing work was conducted in 2007 with a further round of testing planned for Galway Bay in 2010. Work is proceeding on a variety of component elements of the technology and a number of larger-scale devices are in planning.

Other: Approximately 7 further devices are at various stages of research, development and demonstration.

Other information

Test Facilities

The OEDU, in collaboration with the Marine Institute, operates a pre-licensed test site in Galway Bay for wave devices of around 1/4 scale. There is no charge for use to device developers. The site has been used by 2 developers and further deployments are planned.

A grid-connected wave energy test facility is being developed at Belmullet off North-west Ireland at an open-ocean and highly energetic wave location. Surveys and geotechnical studies were completed in September 2009, navigation and environmental measurement and monitoring buoys are being installed. Environmental scoping documentation has been prepared and planning is underway. Final technical and electrical specifications are being drawn up for decision in early 2010. The site will provide test-berths for nearshore, mid-water (50 – 60 m) and deep-water (+90 m) devices. Completion and commissioning will take place in 2011 and 2012.

Studies

An initial study on infrastructure and supply-chain issues associated with large-scale deployment of OE projects was completed and a study on the economics of OE was initiated.

Other

The recently established industry organisation – the Marine Renewables Industry Association (MRIA) – has grown substantially and become influential in areas such as planning, grid development and research. MRIA presently has 17 members from a range of disciplines and interests.

EUROPEAN COMMISSION

Thierry Langlois d'Estaintot, European Commission (DG RESEARCH) and Alexandros Kotronaros, European Commission (DG TREN)

EU renewables energy policy context

Renewable sources of energy – wind power, solar power (thermal and photovoltaic), hydro-electric power, tidal power, geothermal energy and biomass – are an essential alternative to fossil fuels. Using these sources helps not only to reduce greenhouse gas emissions from energy generation and consumption but also to reduce the European Union's (EU) dependence on imports of fossil fuels (in particular oil and gas). In order to reach the ambitious target of a 20% share of energy from renewable sources in the overall energy mix, the EU plans to focus efforts on the electricity, heating and cooling sectors and on biofuels. In transport, which is almost exclusively dependent on oil, the European Commission hopes to increase the current target of a 5.75% share of biofuels in overall fuel consumption by 2010 to a 10% share by 2020.

Research and innovation in energy technology are therefore vital in meeting the EU's ambition to reduce greenhouse gas emissions by 60% to 80% by 2050.

However, actions to develop new energy technologies, lower their costs and bring them to the market must be better organised and more efficiently carried out. This is why the European Commission has proposed the Strategic Energy Technology Plan, a comprehensive plan to establish a new energy research agenda for Europe. This Plan is to be accompanied by better use of and increases in resources, both financial and human, to accelerate the development and deployment of low-carbon technologies of the future.

The new approach focuses on more joint planning, making better use of the potential of the European Research and Innovation area, and fully exploiting the possibilities opened up by the Internal Market. In particular, the Plan includes the commitment to set up a series of new priority European Industrial Initiatives focusing on the development of technologies for which working at Community level will add most value. The Plan proposes the strengthening of the industrial research and innovation by aligning European, national and industrial activities; it also proposes the creation of a European Energy Research Alliance to ensure much greater cooperation among energy research organisations as well as improved planning and foresight at European level for energy infrastructure and systems.

More information is included in the SET Plan document, available at: ec.europa.eu/energy/technology/set_plan/set_plan_en.htm .

Undergoing Ocean Energy Projects Supported by the EC

During 2009, a number of ocean energy projects were running with the support of the Seventh Framework Programme (FP7). Two Directorate-Generals of the European Commission are charged with management and monitoring these projects: the Directorate-General for Research (DG Research) for projects with medium– to long-term impact, and the Directorate-General for Transport and Energy (DG TREN) for demonstration projects.

The table below provides a summary of the ocean energy research projects funded or approved by the European Commission in 2009:

Project Acronym	**Start date**	**Duration** [Months]	**Total EC Funding** [M€]
CORES	April 2008	36	3.45
EQUIMAR	April 2008	36	3.99
WAVETRAIN 2	October 2008	45	3.58
SURGE	October 2009	36	3.00
STANDPOINT	November 2009	42	5.07
PULSE STREAM PS1200	January 2010	48	8.01
MARINA PLATFORM	January 2010	54	8.71
ORECCA	Early 2010	18	1.59
WAVEPORT	Early 2010	48	4.59
AQUA-RET 2	Early 2010	24	2.93

Further, The Intelligent Energy Europe programme provides funding for the WAVEPLAM (WAVe Energy Planning and Marketing) project, which started at the end of October 2007 and will run for a period of 36 months.

CANADA

Melanie Nadeau, Natural Resources Canada, CANMET Energy Technology Centre

A continued interest in ocean energy and sustained level of activity has been seen this year in Canada. Funding was allocated to wave and tidal energy projects by national and regional funding agencies. The Ocean Renewable Energy Group held two national conferences with one in Nova Scotia in the spring followed by the second in Ottawa, Ontario, in the fall. This year also saw the first large-scale tidal turbine successfully deployed in Minas Passage in the Bay of Fundy.

Ocean Energy Policy

The Government of Canada has committed that Canada's total Greenhouse Gas (GHG) emissions be reduced by 20 percent from 2006 levels by 2020 and that 90 percent of Canada's electricity be provided by non-emitting sources such as hydro, nuclear, clean coal and wind power by 2020. In support of these goals, a Clean Energy Fund was announced providing $850 million over five years for the demonstration of promising technologies, including large-scale carbon capture and storage (CCS) projects, and renewable energy and clean energy systems demonstrations. It also provides $150 million over five years for clean energy research and development (R&D). A call for proposals was issued in May 2009 for renewable energy and clean energy systems demonstration projects. Marine energy demonstrations were specifically mentioned as part of the scope for projects of interest. This call closed in September and results have yet to be announced.

The province of British Columbia has a policy directive to allow access to Crown lands for the investigative stages of offshore renewable projects and is finalizing an Ocean Energy Operational Policy that will include occupational licenses for ocean energy projects. The British Columbia Innovative Clean Energy (ICE) fund is supporting a range of clean energy projects including $6M CAD allocated to three marine energy projects.

New Brunswick has committed to have 10% of its electrical energy generated from renewable energy sources by 2016 and the provincial Government is developing its policy on a process to allocate Crown lands for tidal-in-stream energy conversion projects. The land tenure system for tidal projects will involve an allocation framework for each phase of a project, the application and the operational requirements, as well as the monitoring guidelines.

The Government of Nova Scotia has continued to provide support for the tidal demonstration facility located in the Bay of Fundy. Nova Scotia has supported the development of a tidal energy test bed in the Minas Channel with three turbine designs scheduled for installation beginning in late 2009 that will undergo four years of field testing and evaluation. In September, the Environment Minister approved the project environmental assessment conditional on the facility developing a comprehensive environmental effects monitoring programme and establishing an environmental effects advisory committee.
The Ontario Government has introduced the Green Energy Act aimed at investing in renewable energy projects and increasing conservation, while creating green jobs and economic growth for the province. The Act establishes feed-in-tariffs, access to the electricity grid, a one stop streamlined approval process and the implementation of a 'smart' power grid to support the development of new renewable energy projects.

Research and Development

This year, the Nova Scotia's Offshore Energy and Environmental Research (OEER) Association announced eight projects related to tidal energy research in the Bay of Fundy. The research areas being addressed include:

- Tidal Power Potential from Minas Passage and Minas Basin
- Far Field Effect of Tidal Power Extraction on the Bay of Fundy, Gulf of Maine and Scotia Shelf
- Near-Field Effects of Tidal Power Extraction on Extreme Events and Coastline Integrity
- 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 Wood 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

In support of the international standards of International Electrotechnical Commission Technical Committee 114 (IEC/TC 114), a mirror committee has been established (CSC TC 114) to ensure that Canada's views and requirements are well represented. CSC TC 114 consists of stakeholders from across the country including industry, technology developers, utilities, researchers and academia.

Through regular meetings, the Chair and the Vice-Chair can ensure that Canada's participation is active, well represented at international meetings, and contribute to the work programme of IEC TC 114. In addition, the CSC TC 114 is leading the development of the Technical Specification for Marine Energy Terminology (IEC/TS 62600-1).

As IEC/TC 114 continues to create new working groups for standards, CSC TC 114 will ensure that there are representatives on the standards identified as priorities for Canada.

The deployment process of larger turbines presents itself as one of the biggest challenges facing this industry. The combination of waves, winds, and high velocities of tidal currents make this task very unpredictable, and as a result, requires a procedure developed specifically for this application. CanmetENERGY is working with CleanCurrent Power Systems Inc. to develop and model a test procedure to deploy and retrieve a tidal turbine in harsh environmental conditions such as the Bay of Fundy, Nova Scotia. These procedures will be developed through the use of computer simulations, leading to tank test models, and eventually to real-scale sea conditions.

The West Coast Wave Collaboration Program (WCWCP) has been launched which involves a network of researchers, engineers, entrepreneurs and computer modelling experts, who will collect and analyse information on the wave energy potential off of Vancouver Island. The WCWCP involves the deployment of a single fixed buoy off of Ucluelet, British Columbia, where data will be collected and analysed to help answer some of the wave energy questions, including the effects of ocean depth, ocean current and wind influences on wave energy conversion devices. A modelling tool will further be developed and applied as an industry standard.

Verdant Power Inc. and Verdant Power Canada ULC are working together towards optimizing the design of their next-generation Kinetic Hydropower System. Through the Security and Prosperity Partnership of North America (SPP), Canadian partners are collaborating with the US to design, analyze, develop for manufacture, fabricate and test improved turbine system components that will result in larger, higher-power and more cost-effective next-generation systems that will enhance the commercial viability, cost-competitiveness, and market acceptance of promising kinetic hydropower technologies. While Verdant Power Inc. is focusing on optimizing the turbine rotor, the Canadian counterparts will be focusing on designing the optimal electricity generation and interconnection subsystem for the next-generation rotor.

Technology Demonstration

SyncWave Systems Inc. is planning to demonstrate the SyncWave Power Resonator that converts the energy of ocean swells into clean, renewable electricity. This technology is sustainable for both off-grid and grid-integrated applications. This project will be located in Tofino and has been funded by Sustainable Development Technology Canada (SDTC) and the BC ICE Fund. The resonator will have a 100kW nameplate capacity.

The **Canoe Pass Tidal Energy Consortium** (New Energy Corporation Inc., Canoe Pass Tidal Energy Corporation and the City of Campbell River) will develop a commercial tidal energy site at Canoe Pass in a narrow channel between Quadra and Maude Islands north of Campbell River, British Columbia. The commercialization project will involve removal of a causeway, restoration of the tidal current flow and installation of a mechanical span across the pass for two 250 kilowatt (KW) turbines to harness the tidal power. This project has been funded by SDTC and the BC ICE Fund.

Pacific Coastal Wave Energy Corporation is partnering with the District of Ucluelet to build a four-megawatt (MW) demonstration facility to generate electricity from ocean wave power. Located offshore from the community, the technology will be attached to the seabed where submerged buoys harness the ocean's kinetic energy. Since it is deployed underwater, there are no aesthetic concerns and less vulnerability to weather. The project has been partially funded by the BC ICE Fund.

Verdant Power Canada is in the process of obtaining permits for the deployment of their horizontal axis turbine in the St. Lawrence River. The Ontario and Federal Government-funded project, located near Cornwall, will turn the river's strong current into 15 megawatts using the Verdant technology.

Clean Current Power Systems is one of the only Canadian technologies being demonstrated in the Bay of Fundy tidal testing centre. Clean Current has been demonstrating a 65kW turbine in Race Rocks, BC, for the last few years. They have recently signed with Alstom Hydro for an exclusive worldwide license for ocean and tidal stream applications for Clean Current's patented technology. The commercial-scale deployment has been partially funded by SDTC.

The **Fundy Ocean Research Centre for Energy (FORCE)** has commissioned the first turbine with Nova Scotia Power Inc. successfully deploying the OpenHydro turbine in November 2009. The remaining two berths will be occupied in 2010 with Minas Basin Pulp and Power and Clean Current Power Systems.

UNITED STATES OF AMERICA

Robert Whitson, Sentec Inc.

Ocean Energy Policy

2009 saw a continued increase in activity and interest in ocean energy in the United States. In early 2009, the United States Congress appropriated $40 million U.S. dollars (USD) for the U.S. Department of Energy (DOE) – a 400% increase over 2008 levels – to be allocated to advanced water power research in 2009. This amount includes some conventional hydropower technologies, although most was spent on ocean energy. Additionally, the U.S. Congress also allocated $5.9 million USD to 2009 Congressionally Directed Projects in ocean energy technology and project development. The U.S. Navy has continued its support of specific ocean energy projects, including wave, tidal and ocean thermal technologies, and all ocean energy research has been consolidated under its Naval Facilities Command (NAVFAC). Most prominently, the Navy utilized $8 million USD of American Reinvestment and Recovery Act funds to award a project to retire risks related to key Ocean Thermal Energy Conversion (OTEC) components. The two U.S. agencies charged with regulating marine and hydrokinetic energy facilities – the Federal Energy Regulatory Commission (FERC) and the Department of the Interior's Minerals Management Service (MMS) – signed a Memorandum of Understanding (www.ferc.gov/legal/maj-ord-reg/mou/mou-doi.pdf) in April 2009 that clarified each agency's respective role in siting and permitting activities within navigable U.S. waters.

The U.S. continues to be an active participant in both International Energy Agency (IEA) activities and the International Electrotechnical Commission's (IEC) Technical Committee 114 on marine renewable energy standards. The U.S. is the operating agent for Annex IV of the OES-IA, which is chaired jointly by MMS and FERC. Furthermore, as part of DOE's 2009 awards to National Laboratories, Pacific Northwest National Laboratory (PNNL) staff will aid in developing the international database on environmental effects along with the knowledge management system. PNNL will also manage the solicitation for a consultant to carry out activities in support of Annex IV. DOE also supports U.S. industry representation, and serves as the Secretary to the U.S. Technical Advisory Group to the International Electrotechnical Commission's (IEC). In particular, the U.S. is participating in a number of standards committees on "Marine Energy – Wave, Tidal, and Other Water Current Converters" (IEC PT 62600 series), and chairs Part 2: Design Requirements for Marine Energy Systems; and Part 200: The Assessment of Performance of Tidal Energy Converters.

The DOE also continues to identify and characterize device-specific marine energy technologies and projects as they develop. During 2009, DOE partnered with the U.S. Navy to survey technology developers worldwide. The next version of the database is expected for release in January 2010, and will be available on the Wind & Hydropower Technology Program's website (http://www1.eere.energy.gov/windandhydro/).

At the broader Federal level, a number of other departments and agencies are interested and involved in the development of ocean energy. In addition to MMS, FERC, the Navy, and the National Oceanic and Atmospheric Administration (NOAA), these agencies include the U.S. Coast Guard (USCG), the U.S. Fish and Wildlife Service (FWS), the U.S. National Park Service (NPS), the U.S. Army Corps of Engineers (ACOE), and the Environmental Protection Agency (EPA). In January 2009, DOE began convening quarterly meetings with staff from all relevant regulatory and resource agencies in order to create a more coordinated effort among Federal entities.

On the state and local levels, ocean energy must be developed in accordance with each state's coastal zone management plan, which can involve participation, input, and permission from a number of state government resource and regulatory bodies. Many of these agencies and organizations, along with local government and stakeholders, have become active participants in the proposal, siting, and development of offshore energy projects in the United States. As projects require consultation among multiple stakeholders, DOE funded a project in 2008 that recently produced the handbook: Siting Methodologies for Hydrokinetics: Navigating the Regulatory Framework, which is intended to support stakeholders in navigating the regulatory framework by providing clear, brief descriptions of the current federal and state regulatory requirements, outlining the authorization processes, and identifying the agencies involved in these processes.
(http://www.advancedh2opower.com/Resources/Regulatory%20Roadmaps/Siting%20Handbook_12_7_09.pdf)

Research and 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 United States Department of Energy's (DOE) Wind & Hydropower Technologies Program. During 2009, over 10 million USD was awarded to industry members and research organizations for a diverse and complimentary set of projects covering a wide spectrum of ocean energy technologies. These included six energy conversion device or component design and development awards (three in wave, two in tidal current, and one in ocean current) on topics from drive train development and mooring design for current turbines to wave device optimization and validation. DOE also selected eight site-specific environmental studies. These awards were for industry-led teams to perform environmental studies related to the installation, testing, or operation of devices at an open water project site. Finally, DOE made five awards to support market acceleration analysis, including resource and cost assessments. (http://www.energy.gov/news/6554.htm).

DOE also made four awards to National Laboratory-led projects for $8 million across two ocean energy topic areas under DOE's competitive laboratory solicitation. These projects will advance the basic and applied science needed to accelerate the commercial viability, market acceptance, and environmental performance for new marine and hydrokinetic technologies. In the first topic area, projects will produce new science and technology to support industry as it develops more efficient, less costly, and more robust marine and hydrokinetic designs. In the second topic area, awards were made to develop further understanding of the environmental impacts of marine and hydrokinetic devices, so as to minimize the time, costs, and potential environmental risks associated with siting and deploying marine and hydrokinetic systems (http://apps1.eere.energy.gov/news/progress_alerts.cfm/pa_id=233).

Most recently DOE, through its Office of Science, awarded a number of ocean-energy device manufacturers under Phase I of the Small Business Innovative Research (SBIR) program. More awards than normal were made during 2009 due to increased funds made available through the American Reinvestment and Recovery Act (http://www.energy.gov/news2009/documents2009/SBIR_Awards_112309.pdf). Under both solicitations, nineteen awards were made in such areas as power take-off development, materials research, and improved performance.

Within the U.S. university community, a number of institutions have begun formal ocean energy programs. As aforementioned, in 2008 DOE named two National Marine Renewable Energy Centers –located at the University of Hawaii, Oregon State University and the University of Washington – designed to become integrated research, development and open-water testing facilities. Additionally, Florida Atlantic University received state and Federal funding for the Center of Excellence in Ocean Energy Research and Development, which is conducting R&D focused on ocean current energy from the Gulf Stream, and the University of Massachusetts at Dartmouth received funding for the New England Marine Renewable Energy Center (MREC) a consortium that seeks to bring together the required technology, capital, infrastructure, and human resources to implement ocean based renewable energy in the most sustainable manner for the Northeast U.S. A number of other Universities, including Georgia Tech, Virginia Tech, Maine Maritime Academy, and the Universities of Maine, Massachusetts, and New Hampshire – have established R&D programs in ocean energy.

Technology Demonstration

In 2009, U.S.-based companies continued testing and validation of ocean energy devices, but only a handful of companies actually conducted open-water tests, while most continued to perform tank or desktop studies to validate system or component performance.

Those that have put hardware in the water in 2009 include:

- **Verdant Power** successfully demonstrated its grid-connected multi-unit turbine array of tidal energy (New York, NY) in 2008 and 2009, and has since removed units from the East River in order to complete blade design refinements to ensure optimal load distribution.

- **Resolute Marine Energy (RME)** conducted ocean testing of a prototype wave energy converter in early 2009 that produces compressed air for offshore aquaculture operations. Development work was funded by the NOAA and RME's project partners were Ocean Farm Technologies, Inc. and the Massachusetts Institute of Technology (MIT).

- **Ocean Power Technologies (OPT)**, which continues to operate a 40 kW floating point absorber off the Kaneohe Marine Corps Base in Hawaii under a contract with the U.S. Navy's Littoral Expeditionary Autonomous PowerBuoy (LEAP) program.

Organizations moving towards the demonstration phase include:

- **The Snohomish County Public Utility District** has completed engineering design and is currently in the process of completing baseline studies identified during consultation with stakeholders in order to submit a draft license to FERC to construct a tidal pilot demonstration plant in the Admiralty Inlet region of Puget Sound.

- **Ocean Renewable Power Company (ORPC)**, which demonstrated the technical viability of their Turbine Generator Unit (TGU) during 2008, the core of ORPC's proprietary Ocean Current Generation (OCGen™) technology, is planning to deploy a fully grid-connected unit in the Western Passage, near Eastport, Maine, by the end of 2010.

- **Concepts ETI** is concluding development work on an articulated-blade turbine for a floating OceanLinx Oscillating Water Column wave energy converter (WEC), to be deployed and tested in Hawaii during 2010.

- **Pacific Gas & Electric**, the largest investor-owned utility in the U.S., was granted $4.8 million USD from the California Public Utilities Commission during March 2009, and is continuing engineering through 2010 on their Humboldt WaveConnect project, and will begin Environmental Impact Analysis for environmental permit applications.

BELGIUM

Pieter Mathys, Julien De Rouck (Ghent University); Gabriel Michaux (Federal Public Service of Economy SMEs, self-employed and Energy)

Ocean Energy Policy

The Flemish Government has voted a new decree to support electricity production from renewable (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.

Research and Development

The Belgian Science Policy (BELSPO) funded 2 projects regarding offshore energy. The first, Optimization of Basic Knowledge of Offshore Energy on the Belgian Continental Shelf (OPTIEP-BCP), was finalised at the end of 2009 and made a first estimation of both the wave and tidal natural resource. The report (in Dutch but with English summary) will be made available in the first quarter of 2010 on www.belspo.be.

The second (Belgian Ocean Energy Assessment or BOREAS) will further research the potential with numerical models, and will try to assess the extractable potential as well. The project was launched in 2009. The BOREAS consortium consists of four partners with different and complementary expertise to assess this resource study. These partners are: Ghent University (coordinator), Management Unit of the North Sea Mathematical Models (MUMM), Catholic University of Leuven and Flanders Hydraulics Research.

The Sustainable Economically Efficient Wave Energy Converter (SEEWEC) project, funded under the 6th Framework Programme, was finalised in 2009. The publishable Final Activity Report is available on www.seewec.org.

Two PhD studies were finalised at the end of 2009 at the Department of Civil Engineering of Ghent University. Both were funded by the Flemish Agency for Innovation by Science and Technology.

Other information

In May 2009, Belgium hosted the INORE workshop. INORE is the International Network on Offshore Energy and facilitates networking amongst early stage researchers and PhD students.

GERMANY

Jochen Bard, Fraunhofer IWES

After a very strong interest towards renewable energies in general including ocean energy – in the public as well as in research over the last years an increasing number of companies is becoming involved into the sector. Due to limited domestic ocean energy resources compared to other forms of renewables, the focus of the interest is rather on the technology development and export than the exploitation of the National resources. The combination of wave energy installations with offshore wind farms to be installed in the German Exclusive Economic Zone (EEZ) is currently seen as a very attractive option.

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 EU 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 the

- 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 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 (Integrated Energy and Climate Programme 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 with in the German 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 ringfencing 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.

A feed in tariff for electricity from wave and tidal energy similar to the tariff for small hydropower is available under the renewable energy act since 2005. These figure have been raised in 2009 to 11.67 €Cent for power plants below 500 kW and 8.65 €Cent up to 5 MW.

The results from a study on the German ocean energy resources, grid integration aspects and synergies with offshore wind as well as the legal framework for licensing installations are expected to be published in the first half of the year 2010.

Research and 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. It funds 14 projects with a total budget of around 50 Million Euro, covering topics concerning the operation and monitoring, foundation and support structures, turbine technology, grid integration and ecology and safety. See http://www.rave-offshore.de for details.

In the ocean energy sector, around 15 R&D institutes and universities are involved into developing wave, tidal current and osmosis power in the framework of mainly European research projects. The National funding in the framework of the National energy research programme for renewable energies was approximately 150 Million Euro in 2008. This programme is open to ocean energy research, but not many proposals could be funded yet. Up to now, three technology projects related to the development of components and concepts for tidal turbines with a total amount of 5.4 Mill Euro have been funded.

The first projects were related to the development a tidal turbine concept and component. Fraunhofer IWES (former ISET) and LtI 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 to Voith Hydro for the development of their 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 planned at a site off the coast of South Korea in 2010.

Technology Demonstration and Projects

Currently there is only one German manufacturer of ocean energy devices. In the year 2005, Voith Hydro – one of the larger hydropower manufacturers of the world – acquired the Scottish company Wavegen. Under the leadership of Voith, Wavegens's Wells-turbine technology has been developed further. Sixteen Wells turbines will be installed in a breakwater system in the Spanish Mutriku harbour (see Spanish Country report for more details). Voith Hydro is also developing a marine current turbine technology as described above. Other German suppliers such as Bosch Rexroth, Schaeffler and Contitech deliver components and parts for a number of ocean energy devices – for wave as well as tidal turbine technologies mainly in Europe.


Voith Hydro's tidal turbine concept

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 Euro.

There is no installation realised in Germany yet and no recent plans for installations were published.

NORWAY

Tore Gulli, Fred Olsen

Due to the good 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. The governmental support and encouragement for developments in the short term (2-5 years) is weak and an acceptable support mechanism is not yet in place. A green certificate mechanism together with Sweden has been announced in principle for 2012.

Ocean Energy Policy

The Norwegian Government has not yet submitted their previously announced "Energy Bill". A government proposal for allocation, consenting and use of offshore marine resources has been submitted for review. Final decision is not expected until 2012.

Ocean Energy has not been counted as a part of the energy mix in defining the goals for future Norwegian renewable production requirements.

Together with the Swedish Government, an agreement in principle has been reached on the implementation of "green certificates" for renewable energy production. The system will be valid for 2012, but the actual contribution level from the certificates is not known.

Research and Development

No new initiatives were introduced in 2009. However, the overall funding made available through the Norwegian Research Council and ENOVA (new/small scale technology demonstration projects) has increased somewhat. During 2008 ENOVA launched their "Thematic focus on ocean energy" and separate documentation on guidelines for development and qualification procedures for technology developers preparing for grant application.

No new R&D activities were initiated in 2009. Ongoing collaborative program for Ocean Energy at NTNU/Trondheim continues.

Technology Demonstration

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 10 years and that will be capable of making a substantial global contribution to eco-friendly power production.

The prototype that opened at Tofte on 24 November has been in development for more than a year. The plant will have a limited production capacity and is intended primarily for testing and development purposes. The aim is to be capable of constructing a commercial osmotic power plant within a few years' time.

Statkraft's osmotic power prototype

The global potential of osmotic power is estimated to be 1,600 – 1,700 TWh per annum, equivalent to 50% of the European Union (EU) total power production. Osmotic power plants can, in principle, be located wherever fresh water runs into the sea; they produce no noise or polluting emissions and they can be integrated into existing industrial zones, for example, in the basements of industrial buildings.

Statkraft has been researching osmotic power since 1997 and has developed this prototype in co-operation with R&D organisations from many countries. The project has attracted a lot of interest both in Norway and abroad and a number of foreign guests attended the opening.

Hydra Tidal Energy Technology

Hydra Tidal Energy Technology has since 2001 developed Morild, a floating power plant that can produce electricity from coastal currents, ocean currents and tidal currents. The company is currently building Morild as a full scale prototype ready for demonstration by fall 2010. The project is supported financially by Statkraft and ENOVA.

What sets Morild apart from other technologies is its patented mooring and buoyancy system. This makes Morild able to produce electricity in surface position both at shallow (>24 m) and deeper (> 300 m) waters. The technology is designed to avoid costly seabed installation and to operate with low maintenance costs.

Each plant features 4 contra rotating turbines with turbine blades made out of glued wood. Turbine blades made out of this material are environmentally friendly, durable, have a long life span and can be recycled in a bio heating plant. Each turbine has a diameter of 15-28 meters, depending on the application and water current velocity. Each plant weights over 300 tons and can produce over 5 GWh annually, enough to support over 250 Norwegian households.

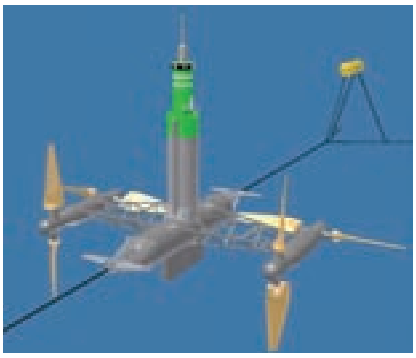
Together with industrial partners, Hydra Tidal is initiating plans for serial production of ready-to-use power plants and has a long term goal of building the world's largest tidal power park on Lofoten Islands in North Norway.
Web site: www.hydratidal.com.

Kinetic Energy

The Norwegian company Kinetic Energy has received funding from ENOVA to deploy their prototype river current energy conversion device. Tests will take place in 2010.

Vattenfall / Tussa Energi

Two full scale energy production units (total installed capacity approx 50 kW) of the Swedish Seabased design were purchased by Vattenfall and deployed at the Runde Environmental Centre on the West coast of Norway in August. The two bottom based units, plus a subsea electrical connection pod will undergo testing the coming years. Following the initial commissioning and tests, the system will be grid connected to the local grid during 2010.


Hydra Tidal Energy Technology

Fred. Olsen

The Norwegian company Fred. Olsen deployed in June 2009 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 2009, "BOLT" had six months of continuous sea operations with only minor inspection and adjustment interruptions, and with MWhs of electricity production.


“BOLT” wave energy prototype installed on the south-east coast of Norway

The device will undergo long-term power production stability and reliability tests throughout 2010.

Langlee Wave Power
The Norwegian company Langlee has developed an innovative floating attenuator unit. The company will build a full scale wave energy converter in the second half of 2010. Offshore engineering is done in cooperation with the companies 4Subsea AS. Dr. Techn Olav Olsen AS and Fedem Technologies and testing of a 1:20 scale model at Aalborg University confirms calculated stability and energy production.

Langlee has signed a Cooperation Agreement with the British shipyard TAG for manufacturing and marketing in the British market. The company has also signed a Letter of Intent with a Turkish customer for the installation of a 24 MW wave power park. Langlee has through 2009 raised NOK 6.7 mill and strengthened its team with a CTO, a CFO and a Business Developer. Langlee has been admitted to the Nordic Cleantech 50 list.

MEXICO

Gerardo Hiriart and Steven Czitrom / Instituto de Ingeniería, UNAM

During 2009, activities in Ocean Energy in Mexico were carried out in 4 areas: Tides, Waves, Currents and Ocean Thermal Energy Conversion (OTEC)/ Hydrothermal Vents. Work continued on the design and potential evaluation of tidal barrages of various lengths to harness the large tidal range (> 6 m) in the northern extreme of the Gulf of California. A potential generation of 1,000 to 40,000 MW for 10 to 75 km long barrages was estimated. Studies continued on a coastal double basin design with a 90 MW potential at Puerto Peñasco, involving a 3 km long barrage. Concerning wave energy, work has continued as expected with a twice as efficient design for the SIBEO wave driven seawater pump. A scale model was built and will be tested in a wave tank before the end of the year. Concerning ocean currents, improvements on the QK floating vertical axis generator system design have been carried out, building on experiences with a scale model in the recent past. Appropriate locations for generating electricity in full-scale systems are the Cozumel Channel in the Caribbean Sea and the Infiernillo Channel in the Gulf of California where a full scale system is estimated to produce some hundreds of KW for current velocities ranging from 1 to 3 m/s. A significant effort has been carried out to identify locations for Very High Temperature OTEC type plants at hydrothermal vents on the seafloor in the Gulf of California. A conservative estimation of the world potential of this source is 160,000 MW (Hiriart, G. IEA-OES, 2009, Oslo). Theoretical estimations place production for large plants in the order of 100 MW, although significant difficulties for the construction and installation of such plants remain to be solved. Smaller land based plants using high-temperature water sources on the shore could be used to either feed the grid or power seawater desalination plants. Last year, legislation was created in Mexico to allow private investment in the field of non-public-utility electricity generation.

Ocean Energy Policy

Legislation recently approved in Mexico opens up possibilities for private investment in the field of non-public-utility electric generation. Previously, this area was restricted exclusively to federal government agencies. Although it is a positive development, the new legislation, which includes a chapter on renewable sources, is somewhat unclear, especially in the designation of the required means for development.

Under the new legislation, an initiative of the Federal Electricity Commission (CFE) is providing support for acquiring existing technology and also for R&D for Mexican ocean energy technology development projects.

Research and Development

The Energy Secretariat (Secretaría de Energía, SENER), in conjunction with the Mexican National Research Council (Consejo Nacional de Ciencia y Tecnología, CONACYT) has recently solicited proposals for alternative energy technology development projects, including ocean energy.

Other institutions involved in R&D: Universidad Nacional Autónoma de México (Instituto de Ingeniería, Instituto de Ciencias del Mar y Limnología) Creación del Sisal en Yucatán, Comisión Federal de Electricidad.

Technology Demonstration

Ocean energy activities in Mexico during 2009 were carried out essentially in four areas: Tides, Waves, Ocean currents and Hydrothermal Vents/OTEC.

Tides

Tides with amplitudes exceeding 6 m in the northern section of the Gulf of California result from a resonant condition with the diurnal frequency of the driving tides at Los Cabos, resulting from the length of the basin.

Presently, the potential of using this tidal range to drive turbines in the flood or the ebb tide or a combination of both, by means of tidal barrage enclosures, is being evaluated.

Estimates of between 1,000 and 40,000 MW for barrage lengths from 10 to 75 km have been made. A double enclosure for continuous electricity production in a coastal lagoon system near Puerto Peñasco, in the northern Gulf of California, requires a barrage of only 3 km long. A production of some 90 MW has been estimated for this system. Additionally, these basins may be used for aquiculture.

Waves

Electricity produced by waves has been considered as one of the most promising renewable energy sources. The estimated potential of 2000 GW is truly vast. Small-scale plants from 100 kilowatts to 2 megawatts are being installed in more than a dozen countries.

In Mexico, the drive to use wave energy has been focused on the development of technologies to pump seawater, useful for the management of coastal ecosystems. Two seawater pumps have been developed at the Instituto de Ciencias del Mar y Limnología, National University of Mexico. One of these systems amplifies the incident waves by means of two converging walls, similar to a Tapchan, to capture the crests in a water collector which drives seawater by gravity to the receiving body of water.

The other system (the SIBEO), amplifies waves by resonance between the driving wave frequency and a mass-spring system comprised by the water in the intake tube and the air spring in a compression chamber. Again, the crests spill water into a collector, which drives a flow to the receiving water body by gravity. During 2009, improvements on the SIBEO design have been made in order to double performance. Before the end of the year, wave tank experiments will be conducted with a scale model of the pump. It is expected that a full-scale system with the new design will pump up to 1 m^3/s with a typical wave climate in Mexico.

Marine Currents

There is a great variety of horizontal and vertical axis turbines that can harness the energy in marine currents. At the Instituto de Ingeniería, National University of Mexico, a floating system with two vertical axis turbines, to be anchored in a marine current to produce electricity, is under development. A scale model of the QK system has been tested successfully at the Ohmsett water canal with a towed gantry from which the performance of the system was measured. MAR, Inc., is the operating contractor of the facility for the United States Department of the Interior's (USDOI) Minerals Management Service (MMS). At present, based on the gained experience, design improvements are being implemented for a prototype to be tested at sea.

Places in Mexico with a good potential for generating electricity from marine currents are the Cozumel Channel in the Caribbean Sea and the Infiernillo Channel in the Gulf of California. At Cozumel, continuous currents average around 1.5 m/s while at Infiernillo, tidal currents have average velocities of 4 m/s. Since the QK system floats tethered to an anchor, it adjusts its orientation to the currents, so that it continues generating electricity independent of changes in the current direction. Theoretical calculations for a full scale prototype estimate generation of up to 60 kW per floating unit for currents between 1 and 3 m/s.

Hydrothermal Vents/OTEC

Stratification in the world oceans provides temperature gradients that can be used to generate electricity with OTEC technology, however Mexico has not participated in this research. During 2009, an important effort has been carried out in Mexico to find sources of high temperature water in the ocean that can be used in an equivalent way.

At sea, relatively accessible high temperature hydrothermal vents can be found principally in four great centers of geological dispersion on the ocean floor: near Vancouver, New Guinea, the Galapagos Islands and the Gulf of California. In the latter, hydrothermal vents are to be found in the Wagner basin in front of Puerto Peñasco, Guaymas, the Ballenas Channel and Tiburón Island. Preliminary estimates show that, for a 10 cm wide vent, with 250°C water flowing at 1 m/s, the available energy would be around 400 TWt. If only a small fraction of this energy should be harnessed, this would be a very promising source of energy. However, many difficulties remain to be surmounted, such as the design and mooring of the appropriate technologies.

Mid-ocean ridges are areas with extremely high heat flow, where temperatures above 300°C can be reached at shallow depths. These high temperatures make them a good target for exploitation of geothermal energy. Therefore, innovating designs to generate electricity by installing a small submarine on the top of the vent with a binary cycle plant have been developed as part of the activities of the IMPULSA project of the Universidad Nacional Autonoma de México (UNAM), which is focused on the utilization of renewable energy sources for desalination of seawater. Results generated by the project for the exploitation of submarine vents have been presented with a description of designs that include calculations of the efficiency of every component. The plants have been designed based on typical values of the vent parameters, and a rough calculation is made on the electricity that could be generated from this renewable resource. The importance of the vents from the ecological and biological point of view restricts the amount of areas that could be used to generate electricity without any drilling, and it is considered that only 1% of the already known sites might be exploited. Under those conservative assumptions, some 130,000 MW of electricity could be generated worldwide. That is almost the same amount of geothermal power that could be generated inland with all the actual and new techniques to generate electricity. It is concluded that prototypes must be tested and exploration of suitable sites must be performed for future electricity generation from hydrothermal vents. One important result, obtained from this research, is that from one hydrothermal vent up to 20 MW of electricity can be produced with a simple method that does not affect the ecosystem.

SPAIN

Jose Luis Villate, Robotiker Energía, Tecnalia

The most important ocean energy resource in Spain comes from waves, with a medium-high potential (between 20 and 60 kW/m) along the Atlantic and Cantabrian coastlines. There are not nationwide wave resource studies so far but a detailed survey is expected in 2010, together with national targets of installed power. There is an important R&D activity with the development of several technologies of wave energy converters but without any full-scale devices tested at sea to date. These technology efforts, together with the establishment of several test and demonstration facilities, predict a promising ocean energy sector in Spain. The consolidation of a new industrial sector will require the support of national and regional governments regarding economic incentives and simpler permitting processes.

Ocean Energy Policy

Current Spanish legislation regards ocean energy in two Royal Decrees from 2007; one establishes the administrative procedure to apply for an authorization for electricity generation installations at sea, and the other one sets the feed-in tariff price, so that the specific tariff is negotiated for every individual project, depending on the investment cost.

Although there are no national targets at the moment, Institute for Diversification and Saving of Energy (IDAE) has started the preparation of a new "Renewable Energy Plan" for the period 2011 – 2020 which will include wave power targets for the first time. For that purpose, IDAE has recently launched a detailed study of the wave energy resource along the whole Spanish coastline based on Geographical Information Systems, which is being performed by the "Environmental Hydraulics Institute – IH Cantabria".

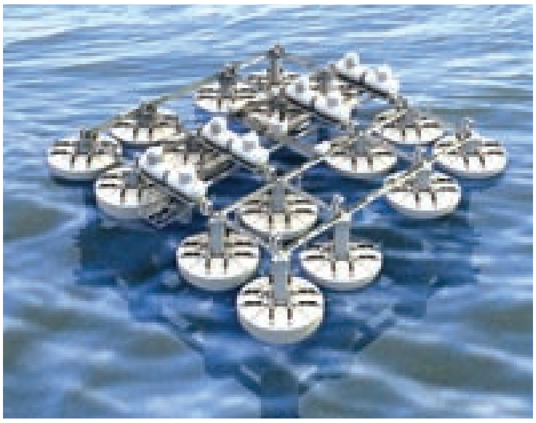
Regional Governments of several areas (the Basque Country, Cantabria, Asturias, Galicia and the Canary Islands) are, on the other hand, promoting the installation of test facilities and demonstration projects. Two of them have set targets on ocean energy so far: the Basque Country plans 5 MW of installed power by 2010, and the Canary Islands consider 50 MW by 2015.

Spain is participating in several international initiatives on promoting ocean energy, being one of the most relevant the European project WAVEPLAM (www.waveplam.eu). 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 ocean 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.

Research and Development

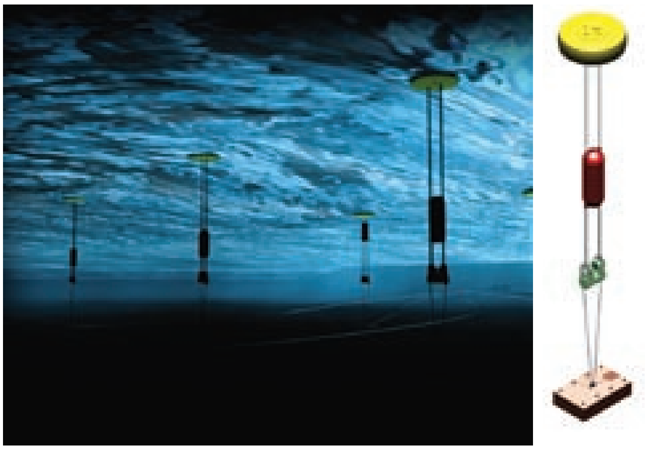
Public R&D investment at a national scale is best represented by the PSE-MAR, a strategic research project funded by the Ministry of Science and Innovation (MICINN). PSE-MAR aims at developing three different wave energy converting technologies, a test and demonstration site and guidance on non-technical issues. This project, coordinated by TECNALIA, is formed by three developers (HIDROFLOT, PIPO Systems and OCEANTEC), industrial companies, R&D centres and universities. In 2008, 3,5M€ were allocated for the period 2008-2010.

HIDROFLOT: The basic production unit will be formed by a 40x40 m platform, located 2 nautical miles from the coast, anchored to the sea bottom by chains and incorporating a 4x4 matrix of 16 hollow columns of some 25 m. length each. The columns are linked together by a collection of horizontal tubes, which provide the lateral stiffness to the column assembly. The platform will behave very much like a floating iceberg. Each column has a buoy which moves upwards and downwards along the column due to the action of the waves. This oscillatory motion activates, for every two buoys, a gearbox machine of reversible motion, which induces a single rotation to a generator of 750 kW. The energy generated is increased to 30 kV and stabilized in frequency. The generated energy is exported to public main distribution by means of an underwater cable. The current status of the Hidroflot's project is between the design and process model stages. The company has done functional requirement definition, development of concepts, control system specification and transmission and generator specification. So they are working in engineering design as a mechanical and structural final design, focused specially in simulated Power Take-Off (PTO) characteristics, survival loading and extreme motion behaviour, mooring arrangements and effects on motion, feasibility and costing.



Hidroflot wave energy platform

APC-PISYS system: PIPO Systems is developing APC-PISYS, the first and unique system of multiple harnessing of the energy of sea waves, in which submerged buoys of variable volume work simultaneously with others in surface. At the moment, the phases of design of the oceanic prototype are being finalized, being predicted their construction, launching and oceanic experimentation between 2010/2011, with installed power of 660 kW per buoy. PIPO Systems is also developing the Welcome Project, again funded by the MICINN. The main objective of this project is the development and demonstration of a 85 kW APC-PISYS prototype, which is planned to be installed in the Canary Islands in the first quarter of 2010.



APC-PISYS system

OCEANTEC: In 2008, IBERDROLA and TECNALIA announced an agreement to develop the Oceantec project, with the goal of putting into operation a wave energy device with high performance and at competitive cost. The OCEANTEC Wave Energy Converter is an offshore floating device. According to its working principle it can be classified as a linear absorber or attenuator. The energy conversion process is based on the relative inertial motion that waves cause in a gyroscopic device. This motion is used to feed an electric generator through a series of transformation stages. The gyroscopic device is located inside a lengthened structure or hull that stays aligned with the wave front, resulting in a pitching motion. Sea trials started in September 2008 with the commissioning on the Basque coast of a quarter scale prototype.

Sea trials of the OCEANTEC prototype

There are other R&D initiatives in progress in Spain:

- **"Wedge Global"** has carried out the manufacturing process of a PTO, based on a switched linear generator (non permanent magnets), which is being implemented at full scale with a 200 kW power output. The linear generator is going to conclude the testing period at the

Cedex-Ciemat facilities at the end of 2009, and is planned to be deployed off shore and grid connected during the summer of 2010.

- **"Abencis Seapower"** has carried out laboratory test of a 1/10 scale prototype during the first half of 2009. In the first half of 2010, Abencis Seapower plans to install a -scale prototype at sea, which is expected to be working for one year. With the information and experience achieved after the sea trials, a demonstration plant will be designed and built.

In the Canary Islands a general marine research infrastructure is under development, which could host ocean energy projects. The Canary Island Oceanic Platform (PLOCAN) is a general marine science and technology mobilisation initiative to install a group of experimentation facilities and laboratories, located on the border of the continental platform. PLOCAN will allow stable oceanic occupation and operations from where it will be possible to access the deep ocean, using and operating, either connected or by remote control, all kinds of vehicles, underwater work machinery and instruments to observe, produce and take advantage of resources.

The end of 2009 saw the announcement of an important R&D project 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, among others, resource assessment, site selection, operation and maintenance, technology development, grid connection or environmental aspects.

R&D activities 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 such as EquiMar (www.equimar.eu), CORES (http://hmrc.ucc.ie/FP7/cores.html) or Wavetrain2 (www.wavetrain2.eu).

Technology Demonstration

Two demonstration projects are currently under construction in Spain:

- **Mutriku, Basque Country:** Nereida Project in Mutriku (Basque Country), promoted by EVE, is an Oscillating Water Column (OWC) integrated in a breakwater and involves a 5.7M€ investment, 4M€ for civil work and the rest for electro-mechanic work and grid connection. The plant consists of 16 turbines, 18.5 kW each, with an estimated overall power of 296 kW. The turbines are expected to be installed at the end of 2009 or beginning 2010 and the plant could start the operations in 2010.

- **Santoña, Cantabria:** IBERDROLA Energías Marinas de Cantabria S.A installed at sea, in September 2008, the first OPT's Powerbuoy of 40kW in Santoña (Cantabria). This buoy was removed from the water to incorporate some technical improvements.

Apart from these two projects already under construction, several other companies are studying the implantation of wave energy plants in Galicia, Asturias, Cantabria, Basque Country and the Canary Islands.

Basque Country and Cantabria Governments intend to set up infrastructures in their coasts during next years to test and demonstrate different technologies of wave energy conversion.

The Basque test facility (bimep – Biscay Marine Energy Plaform) will allow full-scale prototype testing and demonstration of floating wave energy converters up to 20 MW. An oceanographic buoy for monitoring sea and weather conditions was installed in February 2009 and in July the environmental permission was granted by the Ministry of Environment. There are several calls for tenders in progress or to be launched in a near future regarding the subsea cable and its installation, in-land substation and electric installation, offshore connection systems and marking buoys. The bimep infrastructure, promoted by EVE, is expected to be in operation by the end of 2011.

In Cantabria there are two relevant test projects:

- **Test Field of Santoña:** The regional Government of Cantabria has the objective of developing a test site for prototypes of Wave Energy Converters (WECs). The components of this Testing Field are: Testing Field Area, Submerged Substation, Submarine Cable, Land Substation and Control Centre. The Testing Field Area would accommodate up to 10 WEC devices with a maximum combined power of 1.5 MW. The Submerged Substation, located on the sea bed, would accommodate the power to the grid requirements and would transport the electric power to the Land Substation through a Submarine Cable. The Control Centre could be located at the headquarters of the Environmental Hydraulics Institute IH Cantabria (IHc), located some 40km eastwards of the Land Substation in the Scientific and Technological Park of Cantabria.

- **Test Field of Ubiarco:** The objective of the project is to develop a testing site for prototypes of WECs and Floating Wind Turbines (FWT). The components of this Testing Field include Area, Floating Connection Platforms, Submarine Cable, Land Substation, Grid Connection and Control Centre. The Testing Field Area will allocate up to 4 Floating Substations, up to 4 MW each, which will provide connection to a maximum of four devices. The Control Centre will be also located at IHc headquarters. The main industrial partner of this test facility is IDERMAR.

These two test facilities will be supported by "The Great Maritime Engineering Tank" of Cantabria that is being built in the Scientific and Technological Industrial Park of Cantabria. The tank is a maritime and oceanic engineering infrastructure that will have channels to simulate problems similar to coastal ones under different climatic conditions. It is set forth as a unique design in the maritime engineering world as it integrates a system of experimental management, a system of physical modelling and a system of numerical modelling.

Others

The ExCo approved the participation of OES-IA as a partner of the 3rd International Conference on Ocean Energy (ICOE) to be held in Bilbao on 6 – 8 October 2010 (www.icoe2010bilbao.com). ICOE2010 is organised by EVE and TECNALIA, with the partnership of EU-OEA and OES-IA.

This country report has been prepared with contributions from:
IDAE – www.idae.es
APPA (Marine Energy Section) – www.appa.es
EVE – www.eve.es
SODERCAN – www.sodercan.es
TECNALIA – www.tecnalia.info
PIPO Systems – www.piposystems.com
HIDROFLOT – www.hidroflot.com
PLOCAN – www.plocan.eu
Wedge Global – www.wedgeglobal.com
Abencis Seapower
IBERDROLA – www.iberdrola.es
IBERDROLA Ingeniería y Construcción – www.iberdrolaingenieria.com

ITALY

António Fiorentino, Ponte di Archimede and Gerardo Montanino, Gestore dei Servizi Energetici

Increasing Italian interest in harnessing wave and tidal technologies to produce clean and renewable energy can be recognized either in some government initiatives (e.g. the higher incentive for such sources) and in 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 prototypical 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, Law 244/07 has been enacted, which mainly 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 2009 at 5.3 %, increases annually by 0.75% up to 2012. In 2009, the reference price for the GC market was set, by GSE, at 88.66 euro/MWh (VAT excluded). The above-mentioned law also introduced the possibility (but 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 years period.

In the case of wave and tidal energy, this supports mean:

- 1.80 GC/MWh, or
- 0.34 c€/kWh from the feed-in tariff.

The average market price for 2009 was about 64 €/MWh.

According to the recent Law nº 99/09, from 2012 on, the obligation to purchase Green Certificates will pass on electricity suppliers, so Quota Obligation will be modified for this purpose.

Research and Development

Key players involved in research regarding the exploitation of marine tidal and river current to produce energy are universities. Among these, the University of Naples "Federico II" is distinguished for its GEM project. In fact, the ADAG research group of 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 source, named GEM.

GEM project

This 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 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. A special diffuser has been designed to increase the output power for very low speed currents.

After several numerical investigations, a series of experimental tests has 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 a dynamic behaviour and the off-nominal working conditions have been investigated.

Now the full-scale prototype system (100 kW to operate in 2.5 knots water current) is ready to be built and it will be probably installed before the end of 2010 near Venice in a very slow speed current.

Technology Demonstration

Actually there are other two different projects, which involve the ADAG Research Group of the Department of Aerospace Engineering of the "Federico II" University. They are:

- The FRI – EL SEA POWER System
- The KOBOLD Turbine

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 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 reduce 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 has been carried out in the Strait of Messina, in order to check the system well working in real conditions.

On July 2008, a reduced scale of Sea Power prototype (6 kW – 2.5m/s) was launched and in 2009 later 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 full-scale prototype is not yet built but several theoretical analyses, numerical predictions, tests in towing tank and real conditions on a scaled prototype have been already carried out. Permits to deploy the final system are expected for the end of the year.

THE KOBOLD Turbine

The “Kobold Turbine” is conducted 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 m off the coast of Ganzirri, since 2002. The realization of the Enermar prototype has been financed by Ponte di Archimede Company, together with a 50% fund paid by the Sicilian Region Administration (Regione Siciliana), in the Framework of European Union Structural Funds. This project has been disseminated among the developing countries in which the United Nations Industrial Development Organization (UNIDO) operates and the first three countries that have expressed interest were the People’s Republic of China, the Philippines, and Indonesia. A joint venture has been 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 sited 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 could be about 120 – 150 kW.

NEW ZEALAND

John Huckerby, Aotearoa Wave and Tidal Energy Association

There were significant developments in Government policy regarding revisions to the New Zealand Energy Strategy, Emissions Trading Scheme and policies on renewable electricity generation. The new Government continued the Marine Energy Deployment Fund and indicated that a roadmap for marine energy would be developed. Government remained the key investor in marine energy R&D, although the first significant commercial investment was announced in late 2009. Four projects became public, through consultation or applications for resource consents but, by year-end, only a single proof-of-concept wave energy device had been deployed in New Zealand waters.

Ocean Energy Policy

The new National-led coalition Government confirmed its continuing support for ocean energy by continuing existing initiatives, including the Marine Energy Deployment Fund (MEDF) (see below) and continuing support for the Aotearoa Wave and Tidal Energy Association. An award was made from the Second Round of the MEDF on 19 May 2009 (see below) and applications for the Third Round awards ($2 million available) closed on 23 November 2009.

Government officials are preparing a consultation document on replacement of the New Zealand Energy Strategy, which will be released for consultation in early 2010. Meanwhile, the Energy Efficiency and Conservation Authority (EECA) is developing a Marine Energy Road Map, on which consultation is likely to be undertaken during 2010.

During the year a Board of Inquiry heard submissions on the proposed National Policy Statement on Renewable Electricity Generation and is likely to clarify Government’s view on the national importance of development of renewables, including marine energy. The Board of Inquiry submitted a draft report for the consideration of the Minister for the Environment before the end of 2009.

The Government set a target of 20% emissions reductions from 1990 levels by 2020. A Review Committee published its review of the New Zealand's Emissions Trading Scheme (ETS), taking a consensus view that a trading scheme was preferable to a carbon tax. The Government passed the revised ETS into law on 25 November 2009, ahead of the Copenhagen climate change summit. Stationary energy sector joins the ETS in July 2010.

Research and Development

The Government continued to fund three marine energy projects, which first received funding in 2008:

- The Wave Energy Technology – New Zealand (WET-NZ) R&D programme was granted NZ$ 4.8 million over 6 years (2008 – 2014) for R&D on the WET-NZ wave energy converter.
- The National Institute of Water and Atmospheric Research (NIWA) was awarded NZ$ 1 million over 3 years for R&D into tidal energy optimization.
- NIWA is also undertaking a Natural Hazards project, which may provide useful information to device developers/deployers on extreme wave statistics and characteristic.

Technology Demonstration

Wave Energy Technology New Zealand (WET-NZ)

The WET-NZ project began in 2004 and has developed 2nd quarter-scale point absorber wave energy converter (WEC). The two parties, Industrial Research Limited and Power Projects Limited have been awarded NZ$ 4.8 million over six years (from October 2008) for continuing R&D on the WEC. In May 2009, the consortium was awarded NZ $0.76 million from 2nd Round of Marine Energy Deployment Fund for the design, building, commissioning and deployment of a 2nd quarter-scale version of the device. During the remainder of 2009 the consortium focussed on acquiring resource consents for deployment of the 2nd quarter-scale device, gaining international certification for its design and developing relations with international partners.

In mid-December 2009 the consortium successfully deployed its 2nd quarter-scale device off the South Island for a multi-month deployment.

Crest Energy Kaipara Limited

Crest Energy Kaipara Limited was awarded consents for a 200 MW tidal project in the outer part of the Kaipara Harbour, north of Auckland, in August 2008, but the grant of the consents was immediately appealed. The Environment Court heard the appeals in June 2008 and, after lengthy deliberations, announced an interim decision of a "possible positive recommendation" of the consents, subject to consent conditions and an environmental monitoring plan. All being well, Crest Energy Kaipara Limited should be able to proceed with its project in 2010.

During December 2009 Todd Energy Limited, one of the five biggest electricity generators in New Zealand, announced that it had taken a 30% stake in Crest Energy, with an option to take a further 15% in future. This is the first public investment in marine energy by an electricity generator in New Zealand.

Neptune Power Limited

Neptune Power received a consent for a single 1 MW tidal turbine deployment off the south coast of Wellington in April 2008. This was New Zealand's first consent granted for a marine energy project but Neptune Power has reported little progress publicly since that date.

Energy Pacifica

Energy Pacifica has announced plans to submit consent applications for a 20 MW tidal turbine array in the outer part of Tory Channel in the North-eastern part of the South Island. Public consultation began in December 2009 and the consent applications are likely to be submitted early in 2010.

SWEDEN

Susanna Widstrand, Swedish Energy Agency (STEM)

Progress has been very positive during 2009 for Swedish ongoing projects, which have been supported by the Swedish Energy Agency for utilising waves and marine currents.

Ocean Energy Policy

In Sweden, ocean energy projects can apply all year to the Swedish Energy Agency in competition with other renewable energy projects. Government support for all energy renewable sources producing electricity comes from the electricity certificate system. The electricity certificate system is a market-based support system for electricity from renewable energy sources. The system came in to force on 1 May 2003 and runs to the end of 2030. It is intended to increase the production of renewable electricity and also 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 year 2016, compared to year 2002. The system replaces earlier public grants and subsidy systems. The principle of the system is to provide a market place, where sellers and purchasers of certificates can meet.

Research and Development

A second phase of the centre **CFE II-Centre for Renewable Electrical Conversion II** has been formed and started during this year. The continuation also involves, as in phase I, basic research in the areas of wave power, marine currents and wind. This new phase also contains basic theory and calculations, and a whole system approach. The project leader is Professor Mats Leijon from Uppsala University and the timeline is 1 April 2009 to 1 April 2013, with a total budget of € 4.85 million. The centre involves several Ph. D students and several articles have already been published.

The ongoing development project **Research Facility for Wave Power – Lysekil Project Part II** has the timeline from 1 June 2006 to 31 December 2010. The project leader is again Professor Mats Leijon from Uppsala University. The project aim is to study wave power technology under real conditions and the impact from and on the environment. This project consists of ten linear generators standing on the ocean floor, attached to floating buoys.

The experimental facility is located off the West coast of Sweden, in Islandsberg. This site has an acknowledged good wave climate, access to harbours, other modes of transportation and other necessary facilities. Testing at the site will be concluded in 2013 – 2014, after which all the equipment will be removed. A lot of the research activity within the proposed project will be verified experimentally within this full-scale test plant, including technical as well as environmental considerations. In situ wave height measurements, force and acceleration measurements have been made since April 2004. During late autumn/winter 2008 the construction of another two linear generators, #2 and #3 was completed and shipped down to Lysekil. In February 2009, they were deployed at the project site. In June 2009, a substation was launched and the two new generators and generator #1 (already present) were con-

The substation in Islandsberg (courtesy to Uppsala University) nected to the substation. In the same evening, for the first time, the voltage, which is rectified in the substation, and the power from the three linear generators were transmitted to the measurement station simultaneously.

During May 2009, new types of buoys were attached to generator #2 and #3 and a donut-shaped buoy was attached to generator #1.

For more information: http://www.el.angstrom.uu.se/Meny/Eng/index_E.html

Technology Demonstration

The technology demonstration project **Performance Test of Wave System** has a timeline from 15 December 2007 to 31 December 2010. The project leader is Billy Johansson at Seabased AB.

The demonstration project includes manufacturing of prototypes (four 20 kW and one 50 kW linear generators with buoys), launch (at the test facilities Islandsberg-Sweden and Runde environmental centre-Norway), connection, start-up and operation. Every step comprises measurements to control the performance of components and systems. This project is the last step before the technology is ready for the commercial market. Different crucial components will be tested for wear and operational lifetime, extreme forces on buoy and anchors will be assessed to make the converters more reliable and efficient. This step is also intended to develop the system further and adapt it for larger-scale production. This project has been slightly delayed due to change of test site from European Marine Energy Centre (EMEC) to Runde. A 20 kW generator has just been launched in Islandsberg.

For more information: http://www.seabased.se/

AUSTRALIA

Tom Denniss, Oceanlinx

Ocean energy activity in Australia continues to increase, with additional projects due to be installed in 2010, as well as Government funding materialising in the form of the largest grant ever provided to a single ocean energy project in the world.

Ocean Energy Policy

- No Government program specifically for ocean energy exists in Australia at present.
- No Government funding schemes specific to ocean energy currently exist 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 (starting in 2010) which will oversee 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 legislation for a Carbon Pollution Reduction Scheme (CPRS) involving an Emissions Trading Scheme (ETS). The ETS was defeated in the Senate by the opposition conservative party, with the votes of independents in early December 2009. It is anticipated that this legislation will go before the Senate again early in the New Year.

Research and 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.

Technology Demonstration

As part of the Australian Government's REDP fund, **Ocean Power Technologies Australasia (OPTA)** was recently awarded 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 large Australian based company Leightons. The project will require matching funding of 2 for 1, indicating a total project cost of at least $200 million.

Oceanlinx continues to make progress with its next generation version of its Oscillating Water Column (OWC) technology. The original Port Kembla unit, termed MK1, has been decommissioned and is due to be removed from the water imminently. Construction of a new and improved version of the technology, termed MK3, is nearing completion and the unit is due to be installed near the MK1 site at Port Kembla in early 2010. This unit will be a 1/3-scale version of a 2.5 MW commercial unit. A number of commercial follow on projects are being considered in the northern hemisphere. An announcement on these is expected in 2010.

BioPower Systems has made further progress on two pilot projects in Tasmania. The projects involve deployment of a 250 kW bioSTREAM tidal energy system and a 250 kW bioWAVE wave energy system. The company is working with Hydro Tasmania on approvals and grid interconnection. The 250 kW hydraulic/electric power take-off units for both pilots are currently being completed. These units have been developed by BioPower Systems, in collaboration with CNC Design, Siemens and Bosch Rexroth. Fabrication of the complete bioWAVE and bioSTREAM pilot devices is scheduled to commence in 2010.

Wave Rider Energy Pty Ltd is currently in the development stage for a first pilot plant in South Australia near Elliston, Eyre Peninsula. Construction of the pilot plant is scheduled for 2010 with a launch of the pilot in early 2011.

Carnegie Corporation is developing a 5 MW project off Garden Island in Western Australia. The first of its CETO units for this project is expected to be deployed in early 2010. The project is partially funded by a A$12.5 million grant from the Western Australian Government.

Perpetuwave has developed a scaled-concept prototype, which is operational and producing electricity in bay type wave conditions. The company plans to develop a 100 kW (approximate capacity) full scale ocean Wave Harvester to prove the performance projections and longer term operation in open ocean conditions. This is planned to occur within 2 years, funds permitting. From there the company plans to develop a 1 MW unit that will be installed and grid-connected.

Other wave and tidal energy companies in Australia developing technologies include Elemental Energy Technologies, Advanced Wave Power, Ivec, Cetus Energy, Hydro Gen Power Industries, Sundermann Water Power, and Protean Power.

OTHER COUNTRIES

BRAZIL

Francisco M. Miller, from PETROBRAS Research Center (CENPES), with collaboration of Segen Farid Stefen, from COPPE/UFRJ.

Ocean Energy Policy

Ocean Energy in Brazil continues dependent on isolated initiatives from a few companies and universities, with no governmental legislation or strategy.

Research and Development

- A nearshore/offshore wave converter device is being developed by COPPE/UFRJ and PETROBRAS. A first test of a 1:10 reduced model of the device was done at the Ocean Tank in September 2009 and a second test is scheduled for December 2009;
- A Wave Energy Atlas for Brazilian coast was finished by PETROBRAS (not published yet);
- FURG (University of Rio Grande) completed a simulation of ocean conditions on Rio Grande do Sul coast.

Technology Demonstration

Pecém Wave Energy Project: the aim of this project is to install two 50 kW COPPE's shoreline modules at Pecém Port (Ceará coast). It has been developed initially by ELETROBRAS, Ceará State Government and COPPE. Actually it is being developed by Tractebel (brazilian branch), Ceará State Government and COPPE.

- Technology: Hydraulic pumping + Pelton Turbine
- Size: 100 kW (full scale)
- Name: Usina de Pecém
- Location: Pecém Port, Ceará State
- Developer: COPPE/UFRJ, Tractebel, Ceará State Government
- Current Status: Manufacture of equipments
- Funding: Tractebel – complying to ANEEL (Brazilian Electric Energy Agency) R&D investment obligation

Fernando de Noronha Wave Energy Project: the aim of this project is to install a 250 kW power plant on the Fernando de Noronha Island, to generate electricity and desalinate seawater. It will be developed by Pernambuco State Government, COPPE/UFRJ and PETROBRAS, with PETROBRAS and BNDES (National Bank for Social and Economic Development) funds. This plant will be within a National Environmental Preservation Area, and a careful and thorough Environmental Study is been conducted, prior to any concrete initiative.

- Technology: Hydraulic pumping + Pelton Turbine
- Size: 250 kW (full scale)
- Name: Not named yet
- Location: Fernando de Noronha, Pernambuco State
- Developer: COPPE/UFRJ, PETROBRAS and Pernambuco State Government
- Current Status: Memorandum of Understanding has been signed, Environmental Study being conducted
- Funding: PETROBRAS and BNDES

FINLAND

John Liljelund, AW-Energy

Awareness of ocean energy is growing in Finland and there are currently three devices developers in the country. Wave energy represents mainstream as all the concepts are related to electricity generation from waves. AW-Energy, the company behind WaveRoller technology, is the most well known. The other two developers, EcoWave Ltd and Wello Ltd, are in the early stage level and undertaking privately and partly public-funded concept research.

Ocean Energy Policy

There are no national programmes especially for ocean energy, but for renewable energy sector in general.

TEKES (the Finnish Funding Agency for Technology and Innovation) is actively supporting companies that are developing wave energy converters.

Research and Development

National institutions or Universities with activities in ocean energy include VTT Technical Research of Finland, which has some activities on wave energy, and University of Technology Helsinki, which has flume and basin capabilities for scale testing. Some concept testing has been done, but no results are available as testing has been privately funded.

Technology Demonstration

There are no ocean energy projects taking place in the country.

REPUBLIC OF KOREA

Keyyong Hong, Maritime and Ocean Engineering Research Institute, KORDI

The ocean energy research activity and its budget in Korea have been increased steeply in recent years mainly because of investment expansion of Korean Government to renewable energy. As a part of the national campaign of so called “green growth”, the long-term strategy for renewable energy utilization has been announced and it assumes significant contribution from ocean energy resources including the tidal barrage power in a short term as well as both tidal current and wave powers in a long term. In addition, a feasibility study on the ocean thermal energy conversion is currently being carried out.

Ocean Energy Policy

Korea launched its long-term strategy for research, development and demonstration of new and renewable energy in 2008. Its overall target is 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. It requires developing 80% resources of available tidal range and tidal current energy.

Research and Development

In 2009, several R&D projects started as a part of the New and Renewable Technology Development Program supported by the Korean Ministry of Knowledge Economy (MKE). The list of new projects and their principal research organizations is as follows:

1) Development of 300kW HAT tidal current system with fixed structure based on sea trial, Inno & Power Inc.,

Uldolmok tidal current power plant

2) Development of basic technologies utilizing VIV for the ocean renewable energy harvest, MOERI (Maritime and Ocean Engineering Research Institute) of KORDI,
3) Development of a standard S/W system for the integrated design of tidal current turbines, Korea Maritime University.

A national program promoting ocean energy education, research and development in universities was initiated in 2009. The Korea Maritime University and Inha University which offer ocean energy program in their graduate schools were selected and both will be funded by the Korean Ministry of

Sihwa tidal barrage power plant under construction

Land, Transport and Maritime Affairs (MLTM) for 5 years. In addition, the Korea Maritime University was designated as the Key R&D Center for Tidal Current Technologies by MKE.

A feasibility study on the ocean thermal energy utilization in Korean coastal areas is being carried out. It focuses on the thermal energy utilization of deep sea water with multi-purpose use and discharged water from power plants.

Technology Demonstration

Uldolmok TCPP (tidal current power plant) of 1MW capacity was completed in May 2009. It is equipped with a couple of helical turbines of 500kW capacity and the jacket frame is applied as a basic structure. The Uldolmok TCPP includes the installation of upper house for the sheltering of the facility, latticed screen for the protection against floating debris and a catwalk for connection to land. The project, supported by the Korean Ministry of Land, Transport and Maritime Affairs (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.

Sihwa TBPP (tidal barrage power plant) of 254MW capacity is under construction since 2005 and it is expected to be completed in 2010. The construction is followed by making cofferdam, excavation of foundation, developing construction site, gate and turbine housing structure installation, turbine and generator assemble, and cofferdam removal in sequence. The structure and embedded equipment of draft tube liner, bulb case and other embedded materials are currently being constructed and the water turbine generator and gate are expected to be installed in 2009.

Chagwi-Do WPP (wave power plant), a pilot plant of 500kW oscillating water column (OWC) wave energy converter which has been developed by MOERI, KORDI and funded by MLTM, is going to be constructed in Jeju in Korea. A couple of turbines and generators of 250kW capacity will be manufactured in 2010 and then the caisson structure construction and power plant installation will be made at Chagwi-Do test site 1km off the coastline, in 2011.

NETHERLANDS

Peter Scheijgrond and Brecht van der Laan, Ecofys Netherlands BV

The Netherlands are blessed with lots of water, with two main rivers flowing out into the North Sea. Also the Dutch offshore industry and knowledge institutes are renowned worldwide. Still, R&D in the field of ocean energy is relatively low key. The main activities are focussed on osmotic power (Blue Energy) and tidal current energy.

Ocean Energy Policy

In 2009, energy from water saw renewed interest from governmental bodies and other stakeholders in the Netherlands. Although there is (still) no formal policy for ocean energy technologies, the topic is on the agenda for bodies such as SenterNovem, the Ministry of Economic Affairs, Directorate-General for Public Works and Water Management (Rijkswaterstaat) and the institute for water research, Deltares.

In 2009, Deltares and Rijkswaterstaat commissioned a number of feasibility studies into the potential for tidal energy, osmotic power and low-head hydropower in the Netherlands.

The Energy from Water Association (EWA) was established, starting with a network of around 50 stakeholders.

In late 2009, a feed-in tariff for free flow energy (i.e. tidal and river currents) conversion was debated by the Parliament. At the time of publishing this report, the outcome of the debate was still unknown.

Research and Development

- R&D related to ocean energy can be funded through the EOS programme of SenterNovem
- In 2009, the Maritime Innovation Platform added ocean energy as a theme within the Innovation & Research Programme (IOP) with an annual budget of 1.2M€.
- TU Delft, MARIN, TU Eindhoven and Deltares are participating the EMERGO project, Exploration of Marine Energy Research Group, led by Ecofys Netherlands BV
- 3 new PhD students on salinity gradient R&D in Redstack
- 2 young researchers working on floating structures for offshore wave converters at TU Delft

Technology Demonstration

Ecofys C-Energy project

In 2009, a construction was designed and engineered for a 30 kWp-rated tidal turbine, which is suspended from a pier of Total Refinary in the Westerschelde. The turbine has been developed by Ecofys Netherlands BV and is based on a vertical axis type rotor. The consortium, named C-Energy, comprises the city council of Borsele, Total NV and 8 other partners (www.C-Energy.nl). During 2010, an extensive testing programme will be undertaken. Also permit applications are in progress for other locations in the Netherlands.

Installed C-energy in Westerschelde

More information: www.C-Energy.nl

HydroRing

The HydroRing technology is being developed by HydroRing BV. The HydroRing technology is based on a water-driven generator that requires only a low head to generate a reasonable amount of sustainable energy.

In 2009, the focus of Hydroring was on detailing the HydroRing for production and the international market development. The first series are expected to roll of the production line in the 1st quarter of 2010.

- Two of those will be used for the pilot project for Rijkswaterstaat for a live endurance test in the river Maas at the Sambeek locks;
- Two machines are earmarked to go to India for a pilot project in the 1st or 2nd quarter of 2010;
- Remaining machines are to be employed in other countries in pilot projects in the second half of 2010, in co-operation with candidates that enter into a master license agreement.

Impression of a hydroRing in a sluice gate

Tocardo Aqua Inshore at Den Oever – immersion

Tocardo BV Tidal Energy

The Tocardo Aqua series comprises variable speed horizontal axis turbines with a two bladed fixed pitch rotor. A pre-commercial 2.80 m diameter, 45 kW, Tocardo Aqua Inshore turbine was installed this summer in the IJsselmeer barrage near Den Oever. The turbine will be operational for 10 years as a demonstration of tidal energy generation. Plans exist to expand the project with a number of additional turbines.

In October 2008, plans were unveiled to establish a 0.5 MW offshore pilot tidal farm in the Marsdiep sea strait. The farm will consist of six x 10 m diameter Aqua Offshore turbines, suspended from a floating platform. Furthermore, a consortium of companies was set up to develop a 10 MW offshore tidal demonstration farm in the Pentland Firth. Recently, a firm 5 MW grid connection was acquired to feed the future tidal energy into the UK national grid.

More information: www.tocardo.com

Wetsus – REDstack, salinity-gradient energy

REDstack is a spinoff company from Wetsus. The scientific research of Wetsus on the Reverse Electro Dialysis ('Blue Energy') conversion technique is applied at REDstack into a technical design of a stack assembly of membranes and electrodes to generate electricity from salt and fresh water. In 2009, the following projects were executed:

- Industrial pilot (kW-scale) at Frisia Harlingen. Pilot will be overhauled every 4 – 5 months to test newest technology. The first overhaul is carried out in December 2009. At the moment saline wastewater is used. Surface water is planned for the future.
- Start of permitting process for a 50 kW Pilot at the Afsluitdijk.
- Pre-feasibility study for a future power plant of 200 MW in the Afsluitdijk barrage carried out by Royal Haskoning
- Pre-feasibility studies for the Botlek Area (500MW) and "Nieuwe Waterweg" (100 MW) carried out by TU Delft and ECN.

More information: www.redstack.nl

dOmeTEC, ocean thermal energy conversion (OTEC)

A group of four Master students from Delft University of Technology have worked on a project to design a 10MW OTEC Power Plant for installation in the area near Curacao. With innovations like a dome to protect the heat engine, an airlift system to circulate the water, and smart water ducts they have won the Delft Design Challenge and presented their ideas at the conference 'Energy Ocean 2009' in Rockport, Maine, U.S.

More information: www.OTEC.tudelft.nl

SOUTH AFRICA

JL van Niekerk, Stellenbosch University & Thembakazi Mali, SANERI

South Africa has a well recognised wave energy resource at an annual average of 40 kW/m crest length. In addition, the Agulhas Ocean current with a velocity estimated to be between 1.5 to 2 m/s2 is another possible source of ocean energy. With an average tidal range of between 1.5 to 2 m and only a few estuaries, which are mostly in ecologically sensitive areas, tidal rise and fall energy is not a viable resource.

There are two organisations with an active research programme in ocean energy. The national utility company, Eskom, has been characterising the Agulhas ocean current over the last three years but the results of these measurements are not in the public domain. Eskom has also completed a scoping study of feasible sites along the coast of South Africa for possible wave energy conversion. Researchers at Stellenbosch University developed the Stellenbosch Wave Energy Converter (SWEC) and further development of this device is ongoing. A new patent, the **ShoreSWEC**, was filed in 2008 and the device is currently being designed for possible deployment at a very specific site. Funding for research and development is limited, approx Euro 100 000 per annum.

There are no demonstration projects in South Africa and very little commercial activity in ocean energy. Although feed-in tariffs (FIT) for different renewable energy technologies were announced in 2009, there was no FIT determined for ocean or wave energy.

Ocean Energy Policy

Currently there is no specific national policy in South Africa for ocean energy. The White Paper on Renewable Energy published in 2003 did include energy from ocean currents and waves as feasible technologies to pursue, but only in the long term.

Through the South African National Energy Institute (SANERI) limited funding for ocean energy is available. Current projects include linear generators for Wave Energy Converters (WECs), air-flow modelling and turbine design of the Stellenbosch Wave Energy Converter (SWEC) and the design of the ShoreSWEC. In total, the funding for ocean energy in SA is less that Euro 100 000 per annum.

There is no specific support from the South African Government for ocean energy.

Research and Development

SANERI is developing a business plan for a Renewable Energy Centre for Research and Development (RECORD) with a sub-centre in ocean energy positioned at Stellenbosch University. This plan should be rolled out in 2010.

Researchers at Stellenbosch University have been active in the field of ocean energy for a number of years. The Ocean Energy Research Group based at Stellenbosch in the eighties and early nineties studied the ocean energy resource and after concluding that the most promising resource is wave energy developed the Stellenbosch Wave Energy Converter (SWEC). Further development of this device is ongoing with a recent completed project to model the air-flow of the SWEC and design a suitable air-turbine. A new patent based on the original SWEC, the ShoreSWEC which will form part of a harbour wall or breakwater, was filed in 2008 and the device is currently being designed for possible deployment at a very specific site.

The national utility company, Eskom, has been characterising the Agulhas Ocean current over the last three years. Most of the work concentrated on the deployment of acoustic Doppler current profilers to characterise the current over a period of up to three years. This data should now be available but it is not in the public domain. Eskom has also recently completed a scoping study of feasible sites along the coast of South Africa for possible wave energy conversion. Different aspects such as available wave energy, ecological sensitivity, shipping and fishing activities and grid connection were taken into account to identify the most suitable areas along the coast to site a wave energy test and demonstration site.

6. Statistical Overview of Ocean Energy in 2009

The information provided in this section refers to the year 2009 and was compiled from information provided by each delegate member or observer country.

These tables are presently incomplete but the Executive Committee will attempt to provide fuller information in future annual reports.

6.1 Level of Research & Development and Demonstration Investment

Country	R&D		Observations
	Public Investment (M€)	Private Investment (M€)	
Australia	N/A	N/A	
Belgium	0.264		
Brazil		0.39	PETROBRAS and COPPE R&D
Denmark	4.9	12.6	The private investments are more then twice as large as the public investments in Wave Energy.
Finland	0.1	N/A	
Ireland	5	7	
Mexico	2	0.1	Most of the work has been carried out at the National University of Mexico.
New Zealand	0.8	N/A	Private investment very difficult to estimate but probably smaller than public investment. There are, however, a number of parties privately developing tidal turbines and wave devices.
Portugal	0.52	0.55	
Republic of Korea	2.5	0.3	Inclusion of educational promotion programs
South Africa	0.1	0.01	Support for ocean energy research and development is restricted to a few projects with very limited budgets.
Spain	1.6	1	PSE-MAR
	2.1	0.28	Welcome Project
Sweden	1.2	1.3	Only investments that are known by the Swedish Energy Agency
USA	16.6	6.3	Most, if not all private investment came from the overhead funds of the grant award recipients.

6.1 Level of Research & Development and Demonstration Investment

(continuation)

Country	Demonstration		Observations
	Public Investment (M€)	Private Investment (M€)	
Australia	N/A	N/A	
Brazil		1.39	Pecém Project
Finland	0.1	N/A	
Netherlands	0	1	Estimated for all different technologies in development
New Zealand	0.9	N/A	1st Round MEDF award to Crest Energy Kaipara Limited for up to 3 device deployments
	0.37	N/A	2nd Round MEDF award to WET-NZ project for device deployments
		N/A	3rd Round MEDF bid round closed on 23 November; up to NZ$ 2 million available
Portugal		8.5	
Republic of Korea	3.5	1.5	Exclusion of commercial Sihwa TBPP
Spain	0.8	N/A	bimep (test and demonstration facility)
Sweden	0.64	0.70	Only investments that are known by the Swedish Energy Agency
USA	1.15	2.65	Most, if not all private investment came from the overhead funds of the grant award recipients.Agency

6.2 Worldwide Ocean Power Installed Capacity (kW)

	Tidal		Tidal Current		Wave		Salinity	
Country	Installed	Under Installation	Installed	Under Installation	Installed	Under Installation	Installed	Under Installation
Brazil						100		
Canada	20,000		1,065					
Denmark					215			
Korea	254,000	1,000						
Netherlands			80				1	
New Zealand			Nil	Nil	2	Nil	Nil	Nil
Norway							4	
Portugal					400			
Spain						296		
Sweden						50		
UK			1,200		315			

6.3 Electrical Utilities Involved in Research & Development and Demonstration

Country	Utility	Type of involvement
Australia	Hydro Tasmania	BioPower projects in Bass Strait.
	Integral Energy	Oceanlinx Port Kembla project.
Canada	BC Hydro	BC Hydro is working on their Alternative Energy Strategy which should allocate specials funds for emerging technologies.
	NSPI	Deployed OpenHydro tidal turbine in the Bay of Fundy and is chairing the IEC/ TC 114 Canadian Sub-Committee for standards development.
Denmark	Thy-MorsEnergi	Involved in the Wave Star Energy prototype grid connection.
Finland	Fortum	Direct investment to AW-Energy.
Ireland	ESB International	Participation in development of Grid-connected Wave test site.
	Vattenfall	Participation, via joint-venture vehicle, in development of grid-connected wave test site.
Germany	RWE Innogy	Joint venture with Voith Hydro named "Voith Hydro Ocean Current Technologies"
Mexico	Comisión Federal de Electricidad (CFE)	Financial and local support
Netherlands	Eneco	R&D and Project Development
	Nuon (Vattenfall)	Only through the activities of Vattenfall Sweden
New Zealand	Todd Energy	Acquired 30% of Crest Energy Kaipara Limited with option to increase stake to 45%. Further details unknown.
Portugal	EDP – Energias de Portugal, S.A	Technology demonstration and project development
Republic of Korea	Shihwa TBPP	Commercial power plant in 2010
	Incheon-Bay TBPP	Feasibility study
	Uldolmok TCPP	Pilot plant for technology demonstration in 2009
	Chagwi-Do WPP	Pilot plant for technology demonstration in 2011
South Africa	Eskom	Studying Agulhas ocean current and wave energy sites
Spain	IBERDROLA	R&D, technology demonstration and project development
Sweden	Vattenfall AB	R&D direct investment
	Fortum AB	R&D direct investment
	Statkraft AS	R&D direct investment and to Ph.D. students
	Göteborg Energi AB	R&D direct investment
	Falkenberg Energi AB	R&D direct investment
USA	Pacific Gas & Electric	WaveConnect, technology demonstration
	Snohomish Public Utility District	Admiralty Inlet Project, technology demonstration and project development

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