ANNUAL REPORT 2012/

IMPLEMENTING AGREEMENT ON OCEAN ENERGY SYSTEMS

OES | OCEAN ENERGY SYSTEMS

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OCEAN ENERGY SYSTEMS
An IEA Technology Initiative

2012 Annual Report
Published by: The Executive Committee of Ocean Energy Systems
Edited by: Dr. A. Brito e Melo and Dr. J. Huckerby
Designed by: Formas do Possível

INDEX

CHAIRMAN'S MESSAGE

DR. JOHN HUCKERBY
Aotearoa Wave and Tidal Energy Association
OES Chairman 2009-2012

Last year's Annual Report introduced the new face of Ocean Energy Systems (OES) and a new Vision for the future of ocean energy. During 2012 we have been spreading the message of our new mission – to be the **"Authoritative International Voice for Ocean Energy"** – and our Vision. During the year we revised that Vision to include modelling results from the IEA's Energy Technology Perspectives 2012 report, which for the first time included ocean energy in its modelling. Consequently OES and the IEA now speak with a single voice on the future development trends in ocean energy.

During 2010 and 2011 the OES Executive had been working hard to secure a 3rd 5-year mandate to continue operating to promote ocean energy internationally. OES not only produced a new 5-year Strategic Plan but it overhauled its 'brand', by updating its name, its logo and, more recently, its website (www.ocean-energy-systems.org).

The Committee for Energy Research and Technology (CERT) confirmed on 28 February 2012 that OES had successfully secured a 3rd 5-year term and the Executive has been working since that time to begin to deliver the actions outlined in the Strategic Plan. The Executive's meetings this year (in Daejeon, Korea and Aalborg, Denmark) were designed around the Strategic Plan and a number of new Annexes and Activities are in progress or being planned.

During 2012 we have been working with a number of countries, whom have expressed interest in joining OES. These include France, the European Commission, Monaco, Singapore, Malaysia and Nigeria. I am pleased to say that, subject to approval from the CERT, Nigeria will become the 20th member of OES, the first time that any representative from Nigeria has become part of an IEA organization.

Activity levels in ocean energy remain high in NW Europe and North America, whilst interest and activity has been increasing in the circum-Pacific countries. OES is committed to making governments around the Asia-Pacific aware of the potential for ocean energy in their exclusive economic zones. An increasing number of devices continue to be tested or deployed, as the number of operational testing centres, particularly in NW Europe, continues to rise. It is an unusual feature of ocean energy that cross-border collaboration, typified by the OES Executive, continues to be important and the European Union has been in the forefront of encouraging this collaboration.

During 2012 the International Vision for Ocean Energy (version II) brochure has been widely presented and distributed at international ocean energy conferences. The OES is presently consolidating its relationship with the series of International Conferences on Ocean Energy, the most recent of which – ICOE 2012 in Dublin - was probably the largest international conference on ocean energy in the world to date (960 delegates). We hope that ICOE 2014, which will be held in Halifax, Nova Scotia in 29 September – 1 October 2014 will bring together a similarly large and informed audience (www.icoe2014canada.org).

This is my last message as the Chairman of OES. I am happy that I hand over the role to my Vice-Chairman, Mr. Jose Luis Villate of Spain, with the OES Executive in good heart: a strong Annex and Activity programme and a budget to deliver the outcomes of this programme. I cannot end, however, without thanks to all the members of the OES Executive with whom I have had the privilege to work over the last four years, particularly the three Vice-Chairmen, who survived the onslaught of emails from me during their terms with good grace and prompt replies.

Finally, I end with my deep appreciation and thanks to Dr. Ana Brito e Melo of the Wave Energy Centre in Lisbon. She has been the Secretary of OES since I first joined in 2006. She is the heart and soul of the organization and works tirelessly to serve the Executive and its officers. We could not have been so successful without her timely, thoughtful and insightful contributions. It is fitting she gets the next word…

EXECUTIVE SUMMARY

Appreciating the kind words of our retiring Chairman, I would like to take the opportunity to thank Dr. John Huckerby for four inspiring years, in which he consistently put his efforts into enhancing and improving the OES activities and involvement.

The last year had a number of interesting ocean energy developments and some topics of actual importance are reflected in this 2012 Annual Report of Ocean Energy Systems (OES).

Ocean Energy Systems (OES) is the short name for the international technology initiative on Ocean Energy under the IEA, known as the ***'Implementing Agreement on Ocean Energy Systems'.***

Chapter 1 is an introductory chapter addressing the organisational aspects of OES.

Chapter 2 provides information about present membership, a brief description of the current work programme, collaborative activities with the IEA and sponsorship initiatives in which the Executive Committee (ExCo) was involved during the year.

Key accomplishments during 2012 are presented in **Chapter 3**. Membership of the OES involves a commitment to national participation in certain collaborative research activities. Some of these research projects generally have duration of a number of years and are led by an *'Operating Agent'* from a member country, responsible for co-ordinating each project and reporting on progress to the ExCo. Under the OES nomenclature these research projects are defined as 'Annexes' to the Implementing Agreement. The ExCo has also introduced some shorter-term projects (approximately 1 year duration) called 'Activities'. During 2012 the following research projects and activities were conducted:

- Communication and outreach activities, including presentations at 13 international ocean energy conferences around the world;
- Phase II of the International Vision brochure and the respective modelling work in collaboration with the IEA modelling team;
- Research project *"Assessment of Environmental Effects and Monitoring Efforts for Ocean Wave, Tidal and Current Energy Systems"* (Annex IV to be concluded in March 2013);
- Research project *"The Exchange and Assessment of Ocean Energy Device Project Information and Experience"* (Annex V initiated in 2012 and running for 3 years).

Under **Chapter 4** each OES member country presents its national programme activities over the last year, including The Netherlands and France as Observers.

As in previous years **Chapter 5** presents invited papers prepared by subject experts. This year we present four papers based upon a theme of **"Development of the International Ocean Energy Industry – Performance Improvements and Cost Reductions".**

In the first article **"Cost Reduction Pathways for Wave Energy"**, Mirko Previsic (*Re Vision Consulting*), discusses important considerations for evaluating technologies in the US wave energy sector, such as projected costs, uncertainty ranges in the cost assessment process, economies of scale, learning curves and key areas in which cost reductions potentially can be attained within the near-term. He further highlights the need for strong RD&D programs to ensure technology innovation, concluding that *"Nurturing this innovation potential and carefully benchmarking novel concepts and technologies will be critically important over the coming years if substantial cost reductions are to be attained."*

The title of the second invited contribution is ***"ESB Ocean Energy Projects – A Utility Perspective on Cost and Performance Requirements"***. The authors, John Fitzgerald and Fergus Sharkey of ESB (the *Electricity Supply Board*; Ireland's largest electricity utility) describe the cost, performance and revenue requirements for projects at different stages of maturity. During the development of their own wave energy project, WestWave (a 5 MW pre-commercial project in Irish waters), ESB has established readiness, cost and performance criteria to guide suppliers of ocean energy technology towards viable early project investment propositions. The ESB authors conclude that while there are areas of significant cost and performance risk in the medium term, technical fundamentals indicate that ocean energy has the potential to meet the cost trajectory for all forms of renewable energy and contribute to meeting renewable energy targets.

The third invited paper is entitled **"UK Wave and Tidal Projects – Update and Look Ahead"** by John Callaghan from *The Crown Estate*. It gives an overview of recent developments in the UK and the Crown Estate's activities over the last few years. The Crown Estate's strategic objective in wave and tidal energy is to support growth of the emerging industry, attract significant investment to the sector and encourage major players to commit to development, as well as helping Government to define policies that support the development of the industry. As of December 2012, there are 41 wave and tidal projects operational or under development in UK waters (managed by The Crown Estate), with a total potential installed capacity of over 2 GW. This includes test and demonstration facilities, demonstration projects up to 50 MW and commercial projects of 50 MW or greater capacity. The author concludes by stating that a next key milestone for the industry will be installation and operation of the first array projects, which will elucidate operational performance characteristics and costs of these arrays.

"From Turbine Prototype to Prototyping an Industry: a Critical Change in Perspective", is the final article by Chris Campbell and Elisa Oberman of *Marine Renewables Canada* with Tracey Kutney of *Natural Resources Canada*. The paper describes the Canadian Marine Energy Roadmap launched one year ago and the need for a strategy in Canada to achieve a marine industry, by making a parallelism with UK initiatives. The clear focus in Canada's Roadmap was on *"cross-cutting and enabling technologies"*. The main focus of the article is on the challenges to finance and deliver the first array projects and the emergence of a market pull. Critical issues that come along with the scale change from device trials to prototype arrays are discussed, among which are new responses from regulators, supply chain, manufacturers and financiers. The paper concludes that *"demonstration of what this industry will look like and what it can offer"* is essential for the necessary developments and support to make a transition from prototypes to arrays of devices to the development of an industry.

The **final Chapter 6** is a compilation of numerical information provide by all country representatives on: i) Worldwide Ocean Power Installed Capacity, ii) Open Sea Testing Infrastructures, and iii) Electrical Utilities Involved in Research & Development and Demonstration.

Dr. Ana Brito e Melo
OES Executive Secretary

01/ INTRODUCTION

1.1 / ABOUT THE IEA

The International Energy Agency (IEA) is an autonomous agency established in 1974. The IEA carries out a comprehensive programme of energy co-operation among 28 advanced economies, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The aims of the IEA are to:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

To attain these goals, increased co-operation between industries, businesses and government energy technology research is indispensable. The public and private sectors must work together, share burdens and resources, while at the same time multiplying results and outcomes.

1.2 / ENERGY TECHNOLOGY NETWORK

The IEA provides a framework for countries around the world, businesses, industries, international organisations and non-government organisations to work together in collaborative **multilateral technology initiatives**, which enable participants to optimise resources, speed progress and share results. Covering portfolios from basic research to deployment and information exchange on energy supply, transformation and demand, its 42 initiatives (also known as **Implementing Agreements**) focus on:

- Cross-Cutting Activities (information exchange, modelling, technology transfer)
- End-Use (buildings, electricity, industry, transport)
- Fossil Fuels (greenhouse-gas mitigation, supply, transformation)
- Fusion Power (international experiments)
- **Renewable Energies and Hydrogen (technologies and deployment)**

These IEA energy technology initiatives – the **Energy Technology Network** - operates under the guidance of the Committee on Energy Research and Technology (CERT), which has in turn established expert bodies or "Working Parties' to assist with this task. The Renewable Energy Working Party (REWP) is the principal advisory body to the CERT on all matters relating to renewable energies. This particular network comprises ten "Implementing Agreements" on individual technologies:

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

1.3 / OCEAN ENERGY SYSTEMS

The Ocean Energy Systems Implementing Agreement (OES) is an intergovernmental collaboration between countries, to advance research, development and demonstration of technologies to harness energy from all forms of ocean renewable resources, 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 co-operation and information exchange.

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

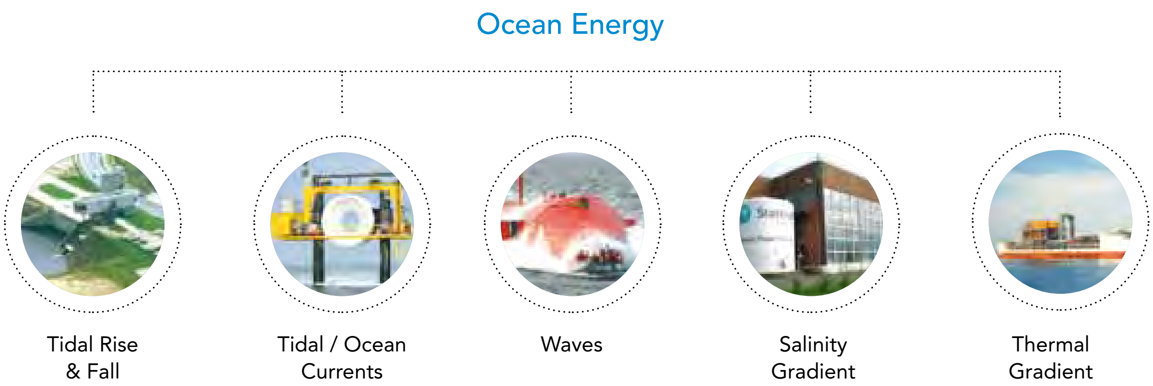


FIG. 1: Principal Forms of Ocean Energy

IEA Implementing Agreements (IAs) operate on a 5-year period called a "term". Before completion of a term, an IA's ExCo can apply for a further 5-year mandate. The grant of a new term involves the submission by the ExCo of an End-of-Term Report, summarizing how the IA fulfilled the aims of its past Strategic Plan, and a new Strategic Plan for the next term.

The current term of OES expired on 28 February 2012. Thus, a request for a new 5-year term, including the End-of-Term Report and a new Strategic Plan, had been submitted to the IEA's Committee on Energy Research and Technology (CERT) in July 2011, and was approved on 1 February 2012.

The OES international co-operation facilitates:

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

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

1.4 / OES'S STRATEGIC PLAN

The Strategic Plan for a 3rd term (2012 - 2016) of the OES has been developed within the context of the founding objectives of the International Energy Agency, coherence with the Strategic Plans of CERT and Renewable Energy Working Party and the need for (and agreement to) a globally accepted Vision for Ocean Energy.

The new Strategic Plan proposes a **new International Vision for OES:**
As the Authoritative International Voice on Ocean Energy we collaborate internationally to accelerate the viability, uptake and acceptance of ocean energy systems in an environmentally acceptable manner.
It identify and prioritises **four Critical Success Factors** for which an action plan for the next 5-year term has been developed:

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

THE OES ROLE

Connect - organisations and individuals working in the ocean energy sector to accelerate development and enhance economic and environmental outcomes
Educate - people globally on the nature of ocean energy systems, the current status on development and deployment, and the beneficial impacts of such systems, improve skills and enhance research.
Inspire - governments, agencies, corporate and individuals to become involved with the development and deployment of ocean energy systems
Facilitate - education, research, development and deployment of ocean energy systems in a manner that is beneficial for the environment and provides an economic return for those involved.

THE OES ORGANISATIONAL VALUES THAT GUIDE OES ACTIONS

Integrity - Any information provided can be relied upon.
Outcome-oriented - We are driven by pragmatic solutions that enhance the global community.
Knowledgeable - All information is based on fact and we ensure that we always have the most relevant and up-to-date researched facts available.
Inspirational - Our performance and our members are committed to providing inspired and collaborative information to accelerate the implementation of environmentally friendly ocean energy systems globally.
Collegial - We are committed to working professionally with each other in the pursuit of our audacious goal.

OES BRAND VALUES

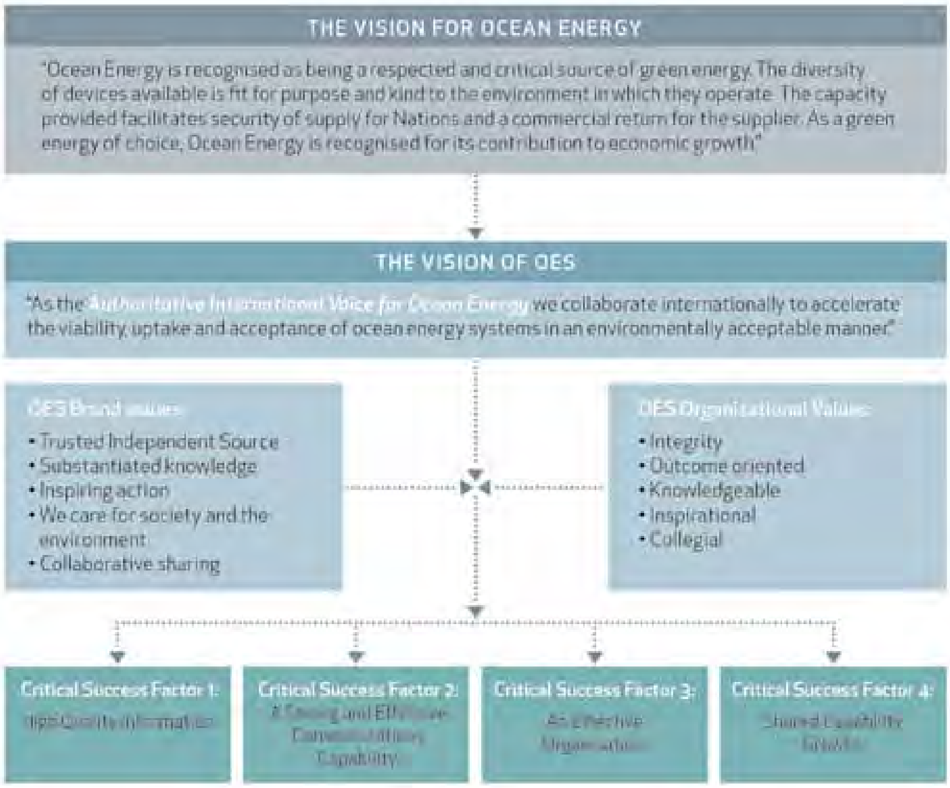
Trusted Independent Source - where the information gained is trusted to be up-to-date, free of any commercial or other vested interests, relevant and practical such that reliance on it will enable forward momentum.

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

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

Caring for Society and the Environment - from every perspective the development of ocean energy systems is done in a manner that enhances the global community, protects the environment and provides a base from which improvement to society will emerge.

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



OES's Vision and Critical Success Factors

02/ REPORT OF THE EXECUTIVE COMMITTEE

2.1 / MEMBERSHIP

The Implementing Agreement on Ocean Energy Systems (OES) was initiated by three countries in 2001. As of December 2011, 19 countries are members of the OES: Portugal, Denmark, United Kingdom, Japan, Ireland, Canada, the United States of America, Belgium, Germany, Norway, Mexico, Spain, Italy, New Zealand, Sweden, Australia, Republic of Korea, South Africa and China ordered by sequence of joining the Agreement (Figure 2).

The European Commission and Nigeria are concluding the process of joining the OES and Nigeria's membership will be formally confirmed by the CERT in February 2013.

In 2012, the Executive Committee unanimously voted to invite Singapore and to re-invite The Netherlands.

Communication continued with other countries invited to join the OES: Brazil, Chile, India, France, Indonesia, Finland and Russia. Some efforts have been done to attract other countries with activities or interest on ocean energy, such as Malaysia, Malta, Costa Rica and Cuba.

A key problem is identifying the appropriate parties in each country and internal government decision-making processes in some countries, which tend to delay completion of the membership process.

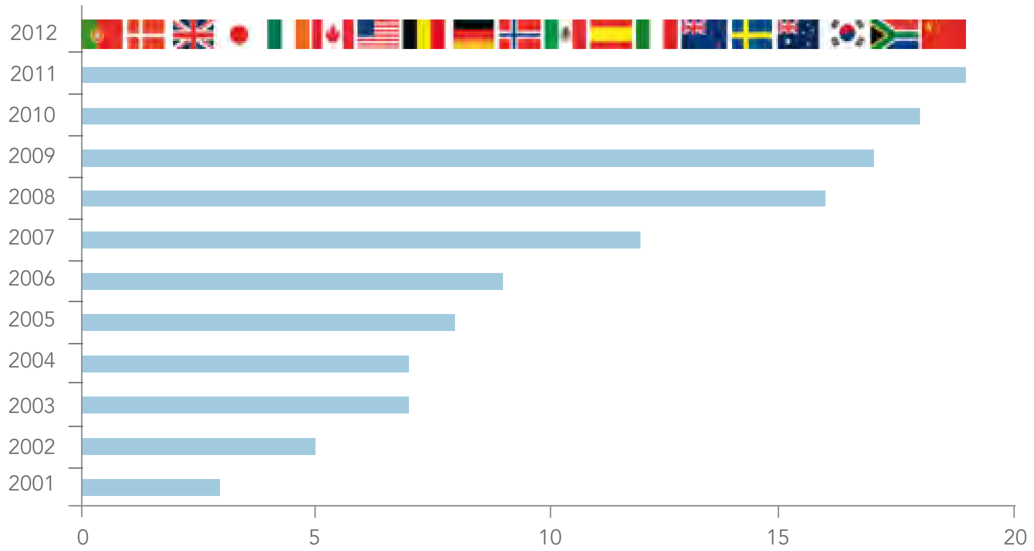


FIG. 2: OES Membership Growth

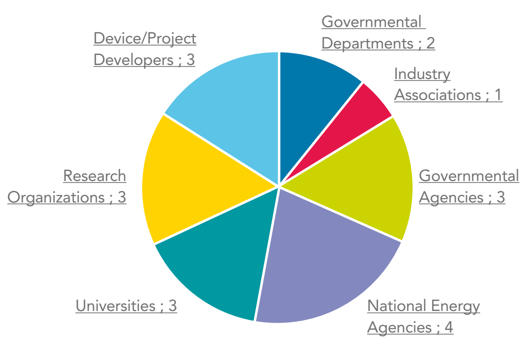


FIG. 3: Diversified representation of interests in the ExCo

National governments appoint a Contracting Party to represent it on the ExCo. The Contracting Party can be a government ministry or agency, a research institute or university, an industry association or even a private company. Governments also nominate alternates, who may represent the government at ExCo meetings, if the nominated representative is unavailable. Consequently there is a diversified representation of interests in the ExCo (Fig. 3). The ExCo considers this diversity to be a key strength of the organization and will strive to maintain this balance of representation.

2.2 / EXECUTIVE COMMITTEE MEETINGS

The Executive Committee (ExCo) is the decision-making body of OES and meets twice a year to discuss its work programme and share information among members. In 2012, ExCo meetings were held in Daejeon, Korea (17 – 18 May 2012) and in Aalborg, Denmark (22 – 23 October 2012). Where possible, the ExCo tries to offer hosting opportunities to all members and to time and locate its meetings to coincide with major international ocean energy conferences.

22nd ExCo meeting

17 – 18 May 2012, Daejeon, Korea

This meeting was hosted by MOERI and the Delegate member from Korea, Dr. Keyyong Hong, was the local organiser of the meeting. The meeting was attended by 22 participants (delegates and guests).
A technical tour to Uldolmok tidal current pilot plant was organized on the 19 May for the ExCo delegates. The delegates were are also invited to attend the OCEANS'12 Conference and Exhibition that was held in Yeosu, Republic of Korea, and to present their national activities on a special session on the 23 May.

23rd ExCo meeting

22 – 23 October 2012, Aalborg, Denmark

This meeting was hosted by the Danish Energy Agency and the Delegate member from Denmark, Dr. Kim Nielsen, was the local organiser of the meeting. The meeting was attended by 29 participants (delegates, observers and guests). Singapore attended the meeting as Observer for the first time.
The ExCo elected officers through 2013-2014: Mr. José Luis Villate (Spanish delegate) as Chairman and Mr. Eoin Sweeney (Irish delegate) and Mr. Michael Reed (USA delegate) appointed as Vice-Chairs.
At the end of the first day meeting, the participants visited the tank testing facilities at Aalborg University. Further, a site visit to Wave Star and DanWEC in Hanstholm was organized for 24 October.

COUNTRY	22nd ExCo Meeting	23rd ExCo Meeting
Australia	√	√
Belgium	√	√
Canada	√	√
China	√	√
Denmark	A	√
Germany	√	√
Ireland	√	√
Italy	A	A
Japan	√	√
Korea	√	√
Mexico	√	√
New Zealand	√	A
Norway	√	√
Portugal	A	√
South Africa	√	A
Spain	√	√
Sweden	√	√
UK	√	√
USA	√	√
Observers		Singapore The Netherlands European Comission

Legend: A = apologies

TABLE 1: Attendance at 2012 Executive Committee Meetings

2.3 / WORK PROGRAMME & MANAGEMENT

The collaborative research carried out by the OES ExCo is structured in Annexes (Research Projects) and Activities to the Work Programme. With the exception of Annex I (Dissemination & Communication), which is mandatory, membership of Annexes is voluntary and participation is by both cost-sharing and task-sharing. Shorter projects or "Activities" are usually financed by the Agreement Common Fund, while the "Projects", with typical durations of 2 to 3 years may have specific budget, managed by an Operating Agent (OA), to which only participants in the Project contribute.
During 2012, Phase II of the **'International Vision for Ocean Energy'** was supported by the Common Fund. Annexes II and III were completed in 2011. Annex IV entered its final year and Annex V was finally commissioned this year.
Further details on active projects and activities are given in Section 3 and the completed projects are summarised in Appendix 4.

WORK PROGRAMME Annexes	1ST TERM	2ND TERM					3RD TERM					
	2002 - 2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
I. Review, Exchange and Dissemination of Information on Ocean Energy Systems OA: Ana Brito e Melo, Wave Energy Centre - PORTUGAL												
II. Development of Recommended Practices for Testing and Evaluating Ocean Energy Systems OA: Kim Nielsen, Ramboll – Denmark					concluded							
III. Integration of Ocean Energy Plants into Distribution and Transmission Electrical Grids OA: Gouri Bhuyan, Powertech Labs - Canada					concluded							
IV. Assessment of Environmental Effects and Monitoring Efforts for Ocean Wave, Tidal and Current Energy Systems OA: Michael Reed, Department of Energy - USA												
V. The Exchange and Assessment of Ocean Energy Device Project Information and Experience OA: Michael Reed, Department of Energy - USA												

TABLE 2: OES Research Projects (status: Dec. 2012)

The ExCo is presently developing a number of new proposals for new projects and activities on topics of common interest to participants.
Contracting Parties pay an annual membership fee to the Agreement Common Fund, which covers administrative expenses incurred in connection with the ExCo, including the expenses of the Operating Agent for the Annex I on Dissemination Activities. The present membership subscription fee is €7,000, which has been held steady for 3 years.
The ExCo elects a Chair and two Vice-Chairs, who serve a 2-year term. Together with the Secretary, who is the only paid member of the ExCo, the Chair and Vice-Chairs form the Cabinet, which manages the day-to-day decision-making to implement the annual work programme and Agreement Common Fund budget approved by the ExCo. The Cabinet also has a leading role in representing the IA at IEA meetings and workshops and making presentations at international conferences.

2.4 / COLLABORATION WITH IEA INITIATIVES

The OES ExCo continued to co-ordinate its activities with relevant IEA meetings and initiatives. Where possible the ExCo is represented at these meeting by members of the Cabinet or delegates. Any meeting attended by the Cabinet in an official capacity, using Agreement Common Funds, is subject of a meeting report to the ExCo by the representative member.

Energy Technology Perspectives 2012

The ETP 2012 is the International Energy Agency's publication on new developments in energy technology. It demonstrates how technologies can make a decisive difference in achieving the objective of limiting the global temperature rise to 2°C and enhancing energy security. *ETP2012* presents scenarios and strategies to 2050, with the aim of guiding decision makers on energy trends and what needs to be done to build a clean, secure and competitive energy future.

This year the ExCo did collaborate with the IEA's ETP modeling team. The preparation of the OES document in 2012 "International Vision for Ocean Energy" in close collaboration with the IEA modeling team establish cost and deployment trends which served as inputs to the IEA modeling team, thus enabling the IEA to make credible inclusion of ocean energy trend data, for the first time.

More information at:
http://www.iea.org/etp/

Energy Technology Network: Energy Technology Initiatives 2012

The IEA has been during 2012 updating results IAs wants to showcase in a Spotlight section of the Energy Technology Initiatives 2012 report. The OES provided inputs on the most relevant OES achievements in 2012: new Annex V initiated during the year and the OES International Vision.

Joint IRENA/IEA-RETD workshop "Levelised Costs of Renewable Energy: What if costs continue to drop?"

26 October 2012, Bonn, GERMANY

The intention of this IRENA and IEA-RETD workshop was to bring together industry representatives, scientists and policy-makers to discuss the recent developments in RET costs and the future implications of these developments. The costs of many Renewable Energy Technologies (RET) have dropped significantly in recent years due to a virtuous circle of high learning rates and increased RET deployment. At the same time, the impact of integrating larger shares of renewables into electricity systems is becoming more apparent. Institutions, including IRENA and IEA-RETD, are studying the issues and the implications surrounding these developments.
The German delegate attended this workshop.

More information at:
http://iea-retd.org/archives/events/irena-and-iea-retd-workshop-on-levelised-costs-of-renewable-energy

2.5 / SPONSORSHIP

Ocean Energy Systems provides financial and Non-financial sponsorship to a number of organizations and ExCo members sit on a number of relevant Steering Committees.

International Conference on Ocean Energy (ICOE)

The ExCo had committed OES to be a non-financial member of the ICOE 2012 conference, which was held on 17 – 19 October 2012 in Dublin, Ireland. ExCo members supported the conference organizer, the Sustainable Energy Authority of Ireland (SEAI), and served on the ICOE 2012 Steering Committee.

The International Conference on Ocean Energy is the global marine energy event focused on the industrial development of renewable marine energy. Held every two years, the goal of the conference and exhibition is to share recent experiences from research and demonstration efforts. It aims to accelerate development by stimulating collaboration networks between companies and research and development centres. It also specifically targets engagement of the experience of operators in related marine and power industry sectors. Over 900 international experts and world-leading companies in ocean energy attended this event.

The OES sponsored a €3,000 prize fund for the best posters presented at ICOE 2012. A 1st Prize of €1,500 and 2 second prizes of €750 each were available to PhD, researchers and other students.

The ExCo further approved the OES would provide a "home" for past and future ICOE 2012 conference material.

Prize First Prize / **Name** Joana Van Nieuwkoop-McCall
Entity University Of Exeter
Title "Evaluation of wave energy resource versus extreme wave conditions at different water depths"

Prize Second Prize / **Name** Lucy Cradden
Entity University Of Edinburgh
Title "A combined resource atlas for marine energy"

Prize Second Prize / **Name** Miguel Santos
Entity Wedge Global S.L.
Title "Testing of a full-scale PTO based on a Switched Reluctance Linear Generator for Wave Energy Conversion"

International Network on Offshore Renewable Energy (INORE)

INORE is a network for postgraduate researchers working with issues related to offshore renewable energy: wave, tidal and offshore wind energy. INORE brings together researchers from around the world to meet, collaborate and share knowledge.

The OES Executive Committee encourages this network and at the last ExCo meeting, the ExCo unanimously agreed to provide annual sponsorship to INORE, particularly to develop membership in new regions, including Asia and the Pacific.

In 2012, OES sponsored the travel costs of the INORE Chairperson to attend the Asian Wave and Tidal Energy Conference (AWTEC) 2012 conference in Jeju, Korea (27-30 November) and promote INORE in Asian region. AWTEC has been established to be the regional conference affiliated to the European Wave and Tidal Energy Conference (EWTEC: www.ewtec.org) series, which has been running since 1979.

The ExCo intends to continue supporting INORE in its development of postgraduate expertise in marine energy.

03/ PROJECT ACTIVITIES

3.1 / DISSEMINATION AND OUTREACH

Operating Agent

Ana Brito e Melo, WavEC, Portugal

Duration

Annex I - Review, Exchange and Dissemination of Information on Ocean Energy Systems is a mandatory Annex of the OES work programme, which has been running since the formation of the OES.

Objective

The objective of this task is to collate, review and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of ocean energy systems. Access to this information should facilitate further development and adoption of cost-effective ocean energy systems. In addition, the results of this task aim to facilitate identification of further annexes, as well as continuing to promote information exchange.

Progress in 2012

The OES communication strategy is described in the Communication Plan 2012 -2016. During 2012, the following activities have been done:

. Website

The OES dedicated website **(www.ocean-energy-systems.org)** is the primary source of communicating the activities of OES to a wider audience and, through the restricted areas, to ExCo delegates. The website was renewed last year and in 2012 a statistical report on the website traffic was prepared covering the first four months the website has been online. In the first four months of 2012 we have reached a total of 10,088 visitors. This is a two-fold increase compared to the old website.

. Online Library

In 2012 the OES developed and launched a web-based library service offered to the public, with relevant documentation on strategy and policy documents, roadmaps and technical reports.

. Annual Report

A professionally edited and printed Annual Report is produced each year and 1,000 copies are widely distributed. This is intended as the flagship document for OES's activities and a marker for industry development. It includes a collection of 4-5 invited papers by international experts on specific themes and national reports from each member country. Members also ensure that the Annual Report reaches its target audience in the respective countries. The publication of the Annual Report was this year accompanied by a worldwide media release.

. OES Bulletin

The 6-page Bulletin issued each semester, immediately after each ExCo meeting presents most updated information exchanged by the delegates. It is available online and was distributed to a wide range of audience in all member countries.

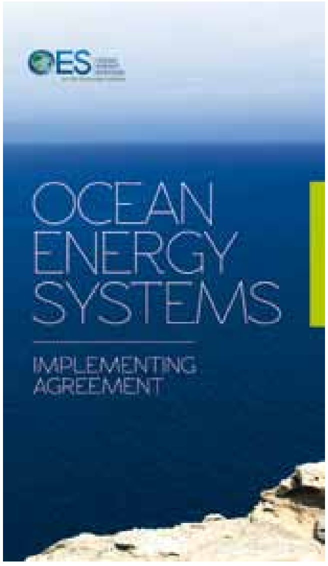
. Promotional Material

A display poster has been produced during 2012 to promote OES at conferences and exhibitions.
A 6-page leaflet was prepared targeting potential new member countries, explaining the role and added value of OES. This leaflet can be delivered to prospective country governments and potential Contracting Parties.

. Exhibition at ICOE 2012

ICOE 2012 included a trade exhibition where many industrial players were present demonstrating the latest technologies in harnessing renewable energy from the sea. For the first time, OES had a stand to display promotional material.

OES Bulletin



OES Flyer

OES Poster

. Translation of the OES in Different Languages

Given the OES is an international organisation looking for foster international support, efforts were made this year to provide information about the OES in multiple languages. A 1-page document about the OES has been translated in the following languages: Chinese, Korean, Japanese, French, Danish, Norwegian, Germany, Italian, Spanish and Portuguese.

. Participation in International Events

Dissemination of OES activities has been an ongoing process, through the presence of OES representatives in well-known conferences related to ocean energy. Such events are the best way to spread awareness about the OES role and activities. The table below lists the different events in 2012, at which OES was represented:

DATE	LOCATION	CONFERENCE
16 – 18 February	Melaka, Malaysia	IOC WESTPAC workshop
7 March	Madrid, Spain	Ocean Energy Conference
19 – 20 April	Wellington, New Zealand	6th Annual Conference
24 - 26 April	Washington DC, USA	GMREC 5th Annual Conference
1 – 4 May	Orkney, Scotland	EIMR conference
21 – 24 May	Yeosu, Korea	Oceans'12 Conference
26 – 27 June	Brussels, Belgium	EU-OEA conference
9 July	Yeosu, Korea	EXPO 2012
5 - 7 September	Rome, Italy	OWEMES 2012 conference
13 – 14 September	Nevis St. Kitts	3rd Caribbean Sustainable Energy Conference
17 – 19 October	Dublin, Ireland	ICOE 2012 Conference
19 – 21 November	Kuala Lumpur, Malaysia	Offshore Structures Asia
28 – 30 November	Jeju, Korea	1st Asian Wave and Tidal Energy Conference

3.2 / ANNEX IV: ASSESSMENT OF ENVIRONMENTAL EFFECTS AND MONITORING EFFORTS

Operating Agent

Michael Reed (USA Delegate), United States Department of Energy (DOE), USA

Duration

Annex IV - Assessment of Environmental Effects and Monitoring Efforts for Ocean Wave, Tidal and Current Energy Systems started in January 2010 and is due to be completed in March 2013.

Participants

OPERATING AGENT *(partners)*	United States: Department of Energy (Federal Energy Regulatory Commission) (Bureau of Ocean Energy Management) (National Oceanic Atmospheric Administration)
TECHNICAL CONSULTANTS	Pacific Northwest National Laboratory (US) Wave Energy Centre (Portugal) University of Plymouth (UK)
MEMBER COUNTRIES	Canada , Ireland, New Zealand, Norway, Spain

Objectives

A wide range of different ocean energy technologies and devices are currently in development around the world. However, data that do exist on the possible environmental effects of these technologies are dispersed amongst numerous countries, researchers 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) highlight any ongoing mitigation strategies, and 4) foster efficient and timely government oversight and public acceptance of ocean energy development. To accomplish these objectives, Annex IV member countries will collaborate to create a searchable, publically available database of research and monitoring information to evaluate environmental effects. The database will include existing syntheses, ongoing monitoring and research projects, case study reports compiled as part of this effort, and select relevant pieces of analogous information from other ocean industries. 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 final report with a worldwide focus on monitoring, collection of data and research occurring for specific high-priority issues of concern. This final report will draw largely on information from the database, and from experts' workshops held as part of the Annex IV project.

Achievements and Progress in 2012

During the first half of 2012, the project's technical consultants heavily focused on further distribution and collection of metadata input forms regarding research and monitoring of ocean energy environmental effects. Metadata forms were also widely distributed by member country representatives, and dozens of forms were collected. During this time Pacific Northwest National Lab (PNNL) integrated this new information into the database developed during 2011 (*Tethys*), performed an external review of database functionality, and began analyzing content to outline the final report.

From April to September of 2012, the final report was written and then reviewed by Operating Agent partners, technical consultants, and member country representatives. It provides a summary of the current science and understanding for three potential environmental impacts of ocean energy technologies: physical interactions between animals and tidal turbines, the acoustic impact of ocean energy devices, and the effects of energy removal on physical systems (e.g. hydrodynamics, sediment transport). Those summaries are presented as case studies within the report and contain descriptions of environmental monitoring efforts and research studies, lessons learned, and an analysis of remaining information gaps for each topic. Although the original concept of case studies was to focus on monitoring efforts around specific marine energy projects, the slower than projected pace of development encouraged a re-examination of the most efficacious topics for case studies. The criteria used to select the three case studies presented in the final report were:

- The topic must be a common environmental concern or question among multiple nations;
- The topic must be raised as a significant issue in permitting (consenting) of marine energy sites in more than one nation; and
- There must be sufficient information available to make an assessment.

On October 15th 2012, the second experts' workshop was held in Dublin Ireland in conjunction with the 4th International Conference on Ocean Energy (ICOE). Fifty-five experts from nine countries participated. The intent of the workshop was to review Annex IV information presented via the *Tethys* database for content and functionality, to review the draft final report with its associated case studies, and to provide substantive comments on these Annex IV products, prior to revisions and publication at the end of 2012. All materials were provided to workshop participants for review four weeks before the workshop occurred.

During the last months of 2012, further updates and revisions were made to the *Tethys* database and final report based on feedback received during the experts' workshop, and preparations were made for the publication of both. The final report for the Annex IV effort will be available on the OES website **(http://www.ocean-energy-systems.org/)**, and users will be able to access the *Tethys* database from there or directly through the PNNL website **(http://mhk.pnnl.gov/wiki/index.php/Tethys_Home)**.

Future Activities

As the three-year Annex IV project draws to a close, it is clear that there are future activities that would support the understanding of environmental effects of marine energy development and continue to meet the goals initially identified under the Annex IV work plan. The amount of environmental monitoring data collected to date has been limited in both scope and scale, as the marine energy industry progresses through the early stages of development. Key environmental questions remain unanswered that future activities could help to inform. The Annex IV Operating Agent (the U.S.) has agreed to commit resources to maintaining and continuing to collect information from around the world for input into the Tethys database. However, continued commitment from other nations would greatly augment the ability to identify and aggregate information on environmental monitoring from marine energy development and research projects around the world. As was noted repeatedly at the second Annex IV experts' workshop, unless the Tethys database is adequately maintained and perceived to contain sufficient quantities of up-to-date information, it will not be utilized by the marine energy community. At the time of this report's publication, the U.S. has engaged the OES member counties to discuss the possibility of extending the Annex IV effort for an additional period, or initiating a new Annex sometime during calendar year 2013. Activities under an extended or new Annex would likely be focused around continued metadata collection and analysis by member nations, formal periodic reviews of the database, and expanded database functionalities as identified during the second expert's workshop. Other potential activities may include partnering with other organizations to host international scientific conferences or workshops, and future publications providing updates on new environmental monitoring or research activities. The most important goal is to ensure that the work completed thus far under Annex IV forms the foundation for future efforts that support the development of a thriving, environmentally sustainable marine energy community around the world.

3.3 / ANNEX V: EXCHANGE AND ASSESSMENT OF OCEAN ENERGY DEVICE PROJECT INFORMATION AND EXPERIENCE

Operating Agent

Roger Bagbey, Cardinal Engineering, under the direction of the United States Department of Energy (DOE), USA

Duration

This Annex entered into force on October 1, 2011 and is due to run until December 2015.

Participants

OPERATING AGENT	United States Department of Energy
MEMBER COUNTRIES	Belgium, Canada, China, Denmark, Germany, Ireland, Japan, Mexico, Norway, New Zealand, Portugal, Republic of Korea, Spain, United Kingdom

Objective

A wide range of ocean energy technologies and devices are currently in development, for wave, tidal, and current resources at many disparate sites. Experiences and data currently being collected on ocean energy projects worldwide can inform ongoing and future projects, and serve to accelerate the realization of operational marine energy converters as a clean energy alternative. The objective of Annex V is to accelerate the development and deployment of ocean energy technology through a multi-country exchange of available ocean project information and experience to allow the participants to understand the current state of knowledge in the field, and to develop a consistent method of assessing the performance and cost of ocean energy conversion systems. The sought after data may include information and experiences from ocean resources, design methods, testing, device performance, and cost of electricity. To accomplish this information exchange, Annex V is organizing workshops which facilitate the review and assessment of projects among member countries and provides recommendations on best practices and gaps in the data that are needed to be accomplished to permit progress of the sector.

Achievements and Progress in 2012

During 2012, Annex V was initiated with a planning meeting in May, where the decision was made for the subject of the first Workshop to be "Open Water Testing." The Workshop was then held in October 2012, with a one and a half day meeting in Dublin, Ireland. Eleven of the fifteen member countries attended the Workshop, which included three sessions: 1) Operational testing facilities; 2) Planned and under-development facilities; and 3) Device developers having conducted open water testing. There were 36 participants from thirteen countries at the workshop with presentations on 16 global testing facilities. A summary report is under development to document issues and recommendations resulting from Workshop I discussions.

Activities Planned for 2013

Year 2 (2013) of the Annex will include the generation of the summary report from Workshop I, and the planning and conduct of Workshop II. A planning meeting will we held in April for the next Workshop, to identify the topic and to generate data requirements for the participants as necessary to permit data presented in the Workshop to be compared and contrasted. Workshop II will be held in the third or fourth quarter of the year.

3.4 / INTERNATIONAL VISION FOR OCEAN ENERGY

Leaders of the Activity

Dr. John Huckerby (Chairman of OES) and Mr. Henry Jeffrey (UK Alternate) with help from Ms. Laura Finlay and Mr. Jonathan Sedgwick (Edinburgh University).

Duration

This Activity was commissioned in April 2011 to follow on from the first phase, which led to the publication of **"International Vision for Ocean Energy"** brochure in October 2011. The second phase work began in earnest in November 2011 and was completed in October 2012.

Objectives

The objectives of this Activity was to update the statistical information cited in the first version of the brochure by collaborating with the IEA's modelling group, who had begun modelling for the biennial Energy Technology Perspectives 2012 publication. For the first time, an IEA publication would include marine energy in its full modelling runs. The revision to the International Vision brochure would thus include peer-reviewed and modelled information from OES and the IEA, helping to fulfil OES's stated mission to become the **"Authoritative International Voice for Ocean Energy"**.

Achievements in 2012

The modelling work with the IEA began in November 2011 with a meeting between the IEA modelling group and the OES Chairman. The International Vision team then sought information on capex and opex costs, learning rates and qualitative resource estimates (by geographic region) for the following forms of ocean energy - wave, tidal current, tidal rise and fall, ocean thermal energy conversion (OTEC) and salinity gradients. Ranges of levelised costs for the first three forms of ocean energy were found relatively easily but costs for OTEC and salinity gradients were much more difficult. This was because OTEC developers were sensitive about releasing commercial cost forecasts and different salinity gradient technologies are still at an experimental stage. In the end the International Vision team could only submit information on wave, tidal current and tidal rise and fall to the modelling.

The first version of the International Vision brochure had been published in September 2011 and was distributed at eight international ocean energy conferences in 2012 as follows:

DATES	LOCATION	CONFERENCE
16 – 18 February	Melaka, Malaysia	IOC WESTPAC workshop
24 - 26 April	Washington DC	GMREC 5th Annual Conference
1 – 4 May	Orkney, Scotland	Environmental Impacts of Marine Renewables Conference
21 – 24 May	Yeosu, Korea	IEE Oceans 2012 Conference
1 June	New York, USA	UNICPOLOS conference, United Nations
26 – 27 June	Brussels	EU-OEA Conference
5 - 7 September	Rome, Italy	OWEMES 2012 conference
13 – 14 September	Nevis St. Kitts	3rd Caribbean Sustainable Energy Conference

The revised version II of the brochure was completed with the assistance of a small project team drawn from the Executive and was finally approved at its meeting in Korea in May 2012. The IEA published the ETP 2012 report in June 2012. OES then printed and distributed the revised version II at the following meetings:

DATES	LOCATION	CONFERENCE
17 – 19 October	Dublin	International Conference on Ocean Energy
19-21 November	Kuala Lumpur	Offshore Structures Asia

Activities Planned for 2013

Version II of the International Vision brochure will continue to be distributed at international ocean energy conferences during the coming year. Funds have been set aside for copies of the brochure to be supplied to Executive members to present the OES Vision, using a customisable Powerpoint presentation and copies of the brochure.

At its October 2013 meeting the Executive will decide whether to commit time and effort to update the input data to the modelling, which the IEA modelling group will begin for the Energy Technology Perspectives 2014 publication.

04/ COUNTRY REPORTS

4.1 / MEMBER COUNTRIES *(ordered by sequence of joining)*

PORTUGAL

Paulo Justino
Laboratório Nacional de Energia e Geologia, IP - LNEG

INTRODUCTION

In 2012, WaveRoller (nearshore bottom-mounted device) was deployed in Peniche (80 km north of Lisbon). Research and development continued to be focused on oscillating water columns (OWC) and point absorbers. Portugal has been participating in several EU projects.

OCEAN ENERGY POLICY

Strategy and National Targets

During 2008, the Government appointed REN – Redes Energéticas Nacionais (National Energy Networks) S.G.P.S., S.A. to create a company to manage the Wave Energy Pilot Zone. In 2010, the Government approved the minutes for the contract with REN – Resolution from the Council of Ministers n049/2010 (1 July), which led to its signature. A company named ENONDAS was created to manage the Pilot Zone. The Government aims to get up to 4MW per technology of installed capacity on the pilot for demonstration purposes and up to 20MW of installed capacity for pre-commercial technology.

Main Public Funding Mechanisms

"Fundo de Apoio à Inovação – FAI". The Innovation Support Fund is intended primarily to finance the national scientific system in the field of innovation and technological development, primarily in the area of renewables, mainly wind power.

FCT (Foundation for Science and Technology) is the main Portuguese national agency responsible for continuously promoting the advancement of scientific and technological knowledge, exploring opportunities that become available in any scientific or technological domain, including marine energy.

Relevant Legislation and Regulation

Legislation is under review aiming to establish new targets to the incentives for renewable energies.

RESEARCH & DEVELOPMENT

Government Funded R&D

The Government acknowledged the need to maintain a group on a national laboratory, Laboratório Nacional de Energia e Geologia, IP (LNEG), performing research and development on ocean energy. The ocean energy group has been working on the development of new concepts for extracting wave energy, namely on the numerical simulation of floating OWCs with alternative geometries. The group has been working on the performance improvement of point absorbers with hydraulic and pneumatic power-take-off (PTO) equipment (self-rectifying air turbines), namely on what concerns the hydrodynamic performance as well as geometry optimization and PTO control. LNEG has been engaged with European Union (EU)

Demowfloat project as well as EU Seanergy 2020 project and to the development of a new roadmap for Portuguese offshore energy. The continuous improvement of a Geographical Information System (GIS) database, developed at LNEG for site selection of wave energy farms, has continued to provide guidance for installation of wave energy devices in the country.

Instituto Superior Técnico (IST) has been active in the development of a spar-buoy oscillating water column wave energy converter. Model testing at scale 1:16 took place in September and October 2012 at the large wave tank of The National Renewable Energy Centre (NAREC),Northern England, within the framework of the European programme MARINET. The work also includes topologies for slack mooring systems of compact arrays. Development work is also being performed at IST on a new type of self-rectifying air turbine, named Biradial turbine, for wave energy applications. Results from model testing indicate that the turbine is capable of remarkably good performance. IST is collaborating with the Portuguese company Kymaner in the design of a prototype of the turbine to be tested at the Pico OWC plant, in the Azores. Another new concept of a floating wave energy converter (WEC) is under investigation and development. It is based on a closed asymmetric floater with an internal U-tank partially filled with water and two lateral reservoirs connected with a tube. During the reporting period improvements have been made on the numerical model of this WEC.

Instituto Superior Técnico will provide, starting in February 2013, a full one-semester specialization on Ocean Renewable Energy (waves, tidal currents, offshore wind), integrated into the three-semester European Master in Renewable Energy organized by the European Renewable Energy Research Centre (EUREC) Agency and involving 11 European Universities.

Participation in Collaborative International Projects

MARINET (2011-2015) - The aim of this project is to coordinate research and development at all scales (small models through to prototype scales from laboratory through to open sea tests) and to allow access for researchers and developers into facilities, which are not available universally in Europe. WavEC and IST are participating in this project.

TROPOS (2011-2015) - "Modular Multi-use Deep Water Offshore Platform Harnessing and Servicing Mediterranean, Subtropical and Tropical Marine and Maritime Resources". The aim is to develop a floating modular multi-use platform system for use in deep waters. WavEC is participating in this project.

SOWFIA (2010-2012) – "Streamlining of Ocean Wave Farms Impact Assessment". The aim is to facilitate the development of European wide, coordinated, unified, and streamlined environmental and socio-economic Impact Assessment tools for offshore wave energy conversion developments. WavEC is participating in this project.

FAME (2010-2012) - "The Future of the Atlantic Marine Environment" - financed by the EC INTERREG IV programme, with the aim to link the protection of natural values, specifically biodiversity (avifauna) with economic activities at the European Atlantic Ocean. WavEC is participating in this project.

WAVEPORT (2009-2012) - "Demonstration & Deployment of a Commercial Scale Wave Energy Converter with an Innovative Real Time Wave by Wave Tuning System", with the aim to demonstrate a large scale grid connected Powerbuoy Technology. WavEC is participating in this project.

DEMOWFLOAT (2011-2014) - The objective of the DEMOWFLOAT project is to demonstrate the long-term Windfloat performance, operationality, maintainability, reliability, platform accessibility, feasible grid integration on a modular basis, among several other aspects with an impact on availability of the system and, therefore, on the cost of produced energy. LNEG and WavEC have been participating in this project.

SEANERGY 2020 (2009-2012) - The objective of the SEANERGY 2020 project is to formulate and to promote concrete policy recommendations on how to best deal with and remove maritime spatial planning (MSP) policy obstacles to the deployment of offshore renewable power generation. LNEG has been participating in this project.

WavEC has been further participating in the project "Structural Design of Wave Energy Devices" (http://www.sdwed.civil.aau.dk/), coordinated by Aalborg University and supported by the Danish Council for Strategic Research and became also involved in two new projects initiated in 2012:

1) SI Ocean "Strategic Initiative for Ocean Energy Development" aiming to identify and develop a wide consensus on the most effective way to tackle the key barriers to delivering a commercial wave and tidal energy sector in Europe, with support from the Executive Agency for Competitiveness and Innovation (EACI) and funded by Intelligent Energy - Europe (IEE).

2) PolyWEC - Electro-active Polymers for Wave Energy Conversion, under the EU FP7 programme.

WavEC and IST are involved in the Offshore Test Station (OTS), funded by KIC InnoEnergy, in which base technology is being developed. This includes development of hardware and software for environmental monitoring, a Remotely Operated Vehicle (ROV) tooling, components and methods for subsea cable connection, a PTO concept for combined wave-wind OWC wave energy converters and operations and maintenance (O&M) software modules for resource forecast & power and platform motions.

Portugal, through WavEC, also participates in the **European Energy Research Alliance (EERA)**.

TECHNOLOGY DEMONSTRATION

Operational Ocean Energy Projects

Pico Plant

On the Island of Pico, Azores, WavEC runs an OWC (Oscillating Water Column; www.pico-owc.net) type wave energy plant, presently among the very few functional wave power plants world-wide. At present, efforts are focused to attract funding for preparing the plant as open test centre, as one full-scale turbine duct in the structure is available. Pico OWC is a unique structure, allowing testing commercially-sized turbines and auxiliary equipments (up to ~700kW). Despite its inclusion in the EC large-scale infrastructure project MARiNET (http://www.fp7-marinet.eu/) and the proof of technology demonstrated over the last 2-3 years, the plant requires substantial investment in order to enable another 5-10 years of service.

New Developments

WaveRoller

The 300 kW WaveRoller unit (3 x 100 kW) has been deployed, near Peniche, deeper than its design depth, in order to collect validation data for previous tank tests and fine-tune the software that enables array optimization for future projects. The device have recently been brought to the surface and towed to the harbour as a part of an O&M exercise. After maintenance and minor repair the power plant will be re-configured and redeployed with only one operational panel. Subsequently, the plant will be deployed with two- and three-panel configurations to gather as much data as possible about the different deployment configurations.

Installation of WaveRoller in Peniche, August 2012

DENMARK

Kim Nielsen
Ramboll

INTRODUCTION

In March 2012, the Danish Government and the opposition entered an agreement on the Danish energy policy for 2012-2020. With the political initiatives in the agreement, the CO2 emission in 2020 will be 34% less than in 1990 and energy consumption will be reduced by 12%. Approximately 35% of the energy will come from renewable resources.

As part of this agreement, DKK100 million [€13 million] is allocated to promote development and use of new renewable electricity production technologies, as well as DKK25 million [€3 million] specifically for wave energy during the period 2012-2015.

In 2012, a new Danish strategy for the development of wave energy was developed by the Partnership for Wave Energy - a partnership between developers of wave energy systems, universities, institutes and industries in Denmark. The project "A new strategy for wave energy through industrial partnership" was initiated by the Wave Energy Research Group from Aalborg University. The project was funded by the Danish Energy Agency's EUDP programme. The strategy is summarized below and the views expressed by the Partnership for Wave Energy do not necessarily represent the views of the Energy Agency.

OCEAN ENERGY POLICY

With the report 'Wave Energy Technology Strategy for Research, Development and Demonstration 2012', the Danish wave energy sector presents a strategy, which aims at the development of cost effective wave energy plants – even more cost effective compared to wind power, when placed far offshore in deep water.

Strategy and National Targets

The vision of the strategy is that Danish industry and businesses will develop competitive wave energy technologies and components to be sold both in the national and the international market. By 2030, wave energy technology can provide a cost-effective and sustainable electricity supply from energy farms located offshore in Denmark.

The development is envisaged to take place through a strengthened and extended industrial cooperation on development of key technology areas identified by the Partnership and through continued demonstration of a selection of different operating principles, in order to identify the most efficient and reliable components, PTO systems, mooring systems and electrical interconnections and grid connections.

DanWEC, placed in Hanstholm in the North Sea, received Greenlab and regional funding of €2 million in 2012 to its first phase of establishment. The strategy suggests demonstration projects to be carried out at DanWEC, partly funded by a grant and partly funded by a conditional and project specific feed-in tariff based on the performance of the device (forskVE/Energinet.dk). Presently, Wavestar is located at DanWEC and the Ocean Energy Systems (OES) group visited the site in connection with the 23rd EXCO meeting in Aalborg as seen in figure 1.

FIGURE 1: Field trip to Wavestar at DanWEC in Hansholm during the 23rd Exco in Denmark

In parallel, priority should be given to basic research that integrates the learning from these field tests into new or improved principles, materials, components and systems leading to more economic second and third generation devices.

The Partnership identified key areas for joint development. These areas are:

- further develop the mooring systems
- further develop PTO systems
- further develop electrical transmission from floating structure to the seabed
- materials and components

Roadmap

The Partnership was asked by the Danish Energy Agency to provide a roadmap towards the development of a 500 MW wave energy plant of in the North Sea.

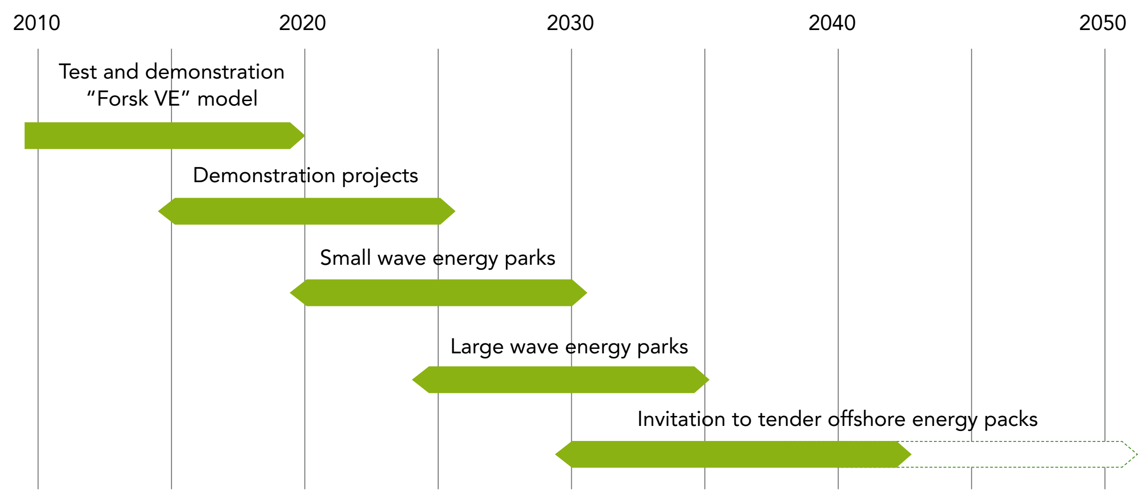


FIGURE 2: Development plan proposed by the Partnership for Waves in Denmark

The plan is roughly presented in table 1 below, indicating four different price levels necessary to perform the development.

YEAR	DEMONSTRATION CAPACITY MW	PRODUCTION LIMIT/YEAR MWH/Y	TARIFF €/MWH
2015 – 2025	2 – 5	7.000	600
2020 – 2030	10 – 20	30.000	400
2025 – 2035	30 – 60	100.000	200
2030 –	500 – 1000	1.500.000	120

TABLE 1: Size of projects and graduation of tariffs for the proposed development

- **Demonstration projects (2015-2025)** up to a total of about 2-5 MW proposed by the Partnership for demonstration purposes (i.e. at DanWEC or Horns Rev offshore wind park) which in terms of energy production are considered suboptimal. The projects will therefore be relatively expensive and to attract private investments the Partnership proposes a feed-in tariff of €600/MWh for a limited annual production of 7000 MWh/year over a maximum of 10 years.
- **Small wave energy parks (2020-2030)** up to a total between 10 – 20 MW, i.e. developed from the concepts that have been demonstrated at DanWEC. These first larger parks would be put for tender on a tariff of €400/MWh with a production limit of up to 30.000MWh/year over a period of 10 years.
- **Large wave energy parks (2025-2035)** up to 30 – 60 MW capacity put to tender with a tariff of €200/MWh with an annual production limit of 100.000MWh/year over a period of 10 years.
- **Cost effective offshore energy park (2030 -)** 500 - 1000 MW capacity put to tender with a tariff of 120€/MWh with an annual production of 1.500.000MWh/year over a period of 20 - 50 years.

This development plan acknowledges that testing and demonstrating hardware at sea is required (even at an early stage with high costs compared to other technologies), in order to gain experience and operating knowledge to carry out the development. The development is accompanied by research and development at a more fundamental level in laboratories, land based test facilities and universities that gradually will enable the more cost efficient schemes.

Energinet.DK has developed a simple new excel based tool that can help calculate the cost of energy produced by the wave energy converter in a standardized way. Any wave energy project supported by Energinet.DK Forsk-VE or Forsk-EL programmes will be required to present the cost of energy and background information. This tool will help focus the development to reach the targets.

Support Initiatives and Market Stimulation Incentives

Public funding authorities will typically require matching private investment even at this relative early stage of development. It is therefore proposed that a project specific feed-in tariff based on the performance of the device (Forsk-VE component in Denmark) is applied for future prototype testing.

The Partnership recommends as illustrated above a conditional funding mechanism – i.e. performance based tariffs that will enable investors to have their investment returned, if the prototype project operates according to a pre-specified performance and maintenance scheme. Even if such tariffs may appear high compared to other sources of energy, the described limits and graduation to lower levels will help support and develop the best systems and gain confidence, incorporating whatever new knowledge, with a minimal risk for the public investment.

Main Public Funding Mechanisms

The main public funding for ocean energy is provided through the **Energy Agency EUDP**, Energinet.DK and the **Danish Council for Strategic Research**. Within **Energinet.DK**, the focus is on bringing the most promising wave energy technologies to proper demonstration and full-scale installations. The price of the electricity generated must be significantly reduced. Together with Forsk-VE, Forsk-EL will make it possible to have selected wave power technologies developed right through to commercial installations.

Relevant Legislation and Regulation

Time limited permits for testing wave energy systems in Danish waters can be obtained at the Danish Energy Agency by submitting one single application, which documents the project. Several Danish developers hold such permits typically for a period of about 2 years.

Relevant documents released

"Wave Energy Technology Strategy for Research, Development and Demonstration 2012" Partnership for Wave Energy, by K. Nielsen, J. Krogh, N. E. H. Jensen, J. P. Kofoed, E. Friis-Madsen, B. V. Mikkelsen, A. Jensen. Aalborg University (DCE Technical Reports;146). The document is available for download at http://goo.gl/uAawr

RESEARCH & DEVELOPMENT

Government Funded R&D

A five year strategic research project "the Structural Design of Wave Energy Devices SDWED", funded by the Danish Council for Strategic Research and co-coordinated by AAU, is ongoing. In Denmark, nearly all development of wave energy systems is funded by the Government and the development of systems has followed a five-step process from smaller laboratory tests to open sea tests - as illustrated in the figure 3 below.

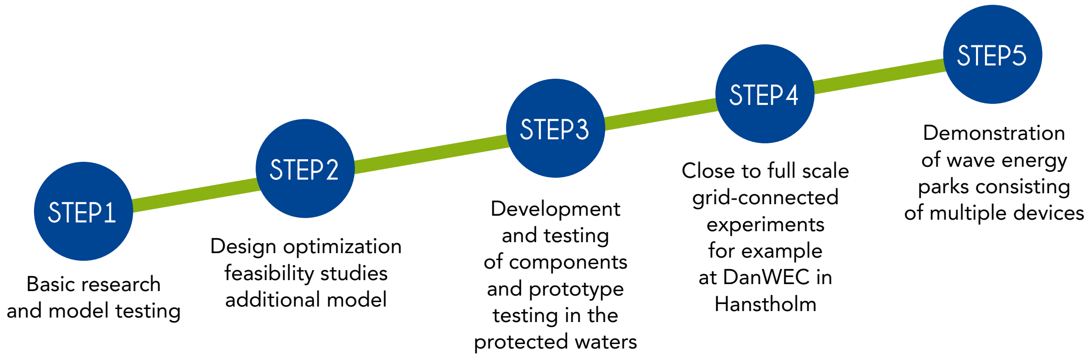


FIGURE 3: The typical Danish stepwise development, stimulating innovation and minimize risk.

TECHNOLOGY DEMONSTRATION

Operational Ocean Energy Projects

Wavestar is currently testing their prototype with two floaters at DanWEC, Hanstholm. Wavestar has an installed generator power of 110 kW and the maximum production measured is 39 kW. Monthly production reports are delivered to Energinet.dk.

Floating Power Plant has commenced the third offshore test phase of their prototype including 140 kW wave power and 33 kW wind power at benign site at the offshore windmill park Vindeby.


▲
Wave Energy demonstration in Denmark of Wavestar (left) and Foating Power Plant (right) at sea.

New and Ongoing Developments

Leancon Wave Energy is preparing to conduct real sea testing at a benign test site Nissum Bredning.

Resen Energy is designing, building and testing a grid connected 2 kW lever operated pivoting float, which is to be tested initially at a benign site and later at DanWEC, Hanstholm.

Wave Dragon is developing a 1.5 MW demonstration device to be tested at DanWEC, Hanstholm. Previously, it has been tested at Nissum Bredning.

Weptos has performed large scale lab testing of a complete machine and has started the process of designing and constructing a full-scale device for testing at DanWEC, Hanstholm.

WaveEnergyFyn is testing at a benign site outside Frederikshavn with their CrestWing scale 1:5 (compared to a planned deployment at DanWEC, Hanstholm).

WavePiston has conducted the first small scale tank testing and is developing a prototype for testing at DanWEC, Hanstholm.

Participation in Collaborative International Projects

Denmark is participating in a number of international projects such as:

- **The European Energy Research Alliance (EERA)** aims to improve cooperation between national research institutes (AAU from Denmark) from the current system of ad-hoc participation in joint projects to a future system of collectively planning and implementing joint strategic research programmes.
- Denmark has considered joining the **ERA-NET** scheme with the aim to step up the cooperation and coordination of research programmes in the field of ocean energy at national and/or regional level in the European Member or Associated States through the networking of organisations involved in the support to ocean energy research and development.
- The **SI Ocean Project** aims to identify and develop a wide consensus on the most effective way to tackle the key barriers to delivering a commercial wave and tidal energy sector in Europe. Denmark participates via DHI.
- **MERMAID (2012 – 2015)** [http://cordis.europa.eu/projects/rcn/101743_en.html] Innovative Multi-purpose Offshore Platforms: Planning, Design and Operation; the project is coordinated by DTU.
- **MARINA (2010 - 2014)** [http://www.marina-platform.info/] the MARINA Platform project will establish a set of equitable and transparent criteria for the evaluation of multi-purpose platforms for marine renewable energy (MRE). Danish participants are Dong Energy and DTU-Risø.
- **MARINET (2011-2015)** [http://www.fp7-marinet.eu/] aims to coordinate research and development at all scales (small models through to prototype scales from laboratory through to open sea tests) and to allow access for researchers and developers into facilities, which are not universally available in Europe. From Denmark, AAU and DTU participate.
- **IEC TC 114** within the development of standards on ocean energy, Denmark is participating in a number of standardization groups.

UNITED KINGDOM

Karen Dennis
Department of Energy & Climate Change (DECC)

INTRODUCTION

The UK wave and tidal industry continues to receive significant support from the UK Government and the Devolved Administrations in Scotland, Wales and Northern Ireland. The mechanism for supporting the industry is channelled through the UK Marine Energy Programme which was implemented in 2010. This programme is aimed at enhancing the UK marine energy sector's ability to develop and deploy wave and tidal energy devices at a commercial scale by concentrating on key areas that affect the sector such as:

- Support needed for small scale arrays and early commercial deployment;
- Planning and consenting issues;
- Island transmission charging
- Knowledge sharing
- Marine energy in the reformed energy market.

The conclusion of the UK Government's and the Scottish Government's consultation on the level of incentives available for wave and tidal energy generation through the Renewable Obligation banding reviews was published in July 2012. Both Governments have confirmed the incentives for wave and tidal stream at 5 ROCs per MWh for projects up to 30MW capacity from 2013-2017.

In addition, the UK Government £20 million Marine Energy Array Demonstrator (MEAD) and the £18 million Scottish Government's Marine Commercialisation Fund (MRCF) will provide capital grant to support the deployment of array schemes by 2016. Competition for these schemes is now closed and announcement of awards will be made in the coming weeks. The Scottish Government also announced a £103 million Renewable Energy Investment Fund (REIF) which will mainly focus on marine energy.

During the year, thirteen (13) different prototype technologies underwent trials simultaneously in the waters off Orkney at the European Marine Energy Centre (EMEC). EMEC continues to attract international interest and has secured contract for all its full-scale berths well into the next few years.

In May 2012, the National Renewable Energy Centre (Narec) officially opened its 3MW marine drive test rig "Nautilus". It aims to perform accelerated lifetime testing of whole nacelles and their individual drive train components such as gearboxes, generators and bearings for tidal devices. Atlantis Resources was the first to commission the Nautilus to test its 1MW AR1000 in the summer.

OCEAN ENERGY POLICY

Strategy and National Targets

The UK Renewable Energy Road Map sets out the Government objectives on energy from renewable sources leading up to 2020. First array demonstration projects are envisioned to be deployed by 2016 with assistance from the MEAD, MRCF and other funding schemes such as the European Commission NER 300. Projections are that commercial scale deployment will then increase through the second half of the decade, reaching in the order of 200 – 300 MW by 2020.

Through the Marine Energy Programme Board (MEPB), the Government is actively engaging with the sector and working with them to realise their potential. The MEPB, which draws together key stakeholders from across the marine energy sector (energy utilities, industrial companies, technology developers, financiers and Devolved Administrations), plays a central role in advising Ministers what actions the Programme should take to advance the industry. The current focus is on enhancing the UK marine energy sector's ability to develop and deploy wave and tidal energy devices at commercial scale. Over the past year, the key areas of focus for the Marine Energy Programme Board has been:

- Island transmission charging
- Support needed for small scale arrays and early commercial deployment;
- Planning and consenting issues;
- Knowledge sharing though a Marine Intelligence Network.
- Level of support for marine energy under the reform of the energy market which is to be implemented in 2014.

The Coalition Government has supported the development of Marine Energy Parks (MEPs) across the UK to help propel the industry forward. MEPs aim to bring together manufacturing, expertise and other activities to drive the marine sector forward to commercialisation.

There are now two MEPs in the UK; the South West Marine Energy Park (SWMEP) which was launched in January 2012 and the Pentland Firth and Orkney Waters (PFOW) Marine Energy Park which was launched in July 2012. The SW MEP has since published its business plan and have received initial funding contributions from a coalition of local partners which will be matched by contributions from the private sector.

The Pentland Firth and Orkney Waters Leadership Forum (PFOWLF) are finalising a marketing and communications plan to take forward actions agreed upon by the forum. The PFOWLF are currently in talks with SW Marine Energy Park colleagues on a number of proposals which will result in collaboration MEP work from 2013 onwards.

SCOTLAND

On 30 October 2012 Scotland published the first annual update to our 2020 Routemap for Renewable Energy in Scotland. This progress report provides a summary of developments across the renewables sector, and includes a new interim target to meet the equivalent of 50% of Scotland's electricity demand from renewable sources by 2015 – an important milestone on the journey towards 100% by 2020. Scotland surpassed its 2011 target of 31% of electricity demand by generating 35% of electricity from renewable sources that year.

In June 2012, Scotland also produced its Marine Energy Action Plan which detailed the five key elements around which it would further develop and support the marine renewables industry within Scotland. These are as follows: 1) Finance, 2) Grid, 3) Infrastructure and Supply Chain, 4) Planning and 5) Europe.

The Marine Energy Action Plan, whilst not a government strategy, is an industry led document that highlights the barriers to the industry whilst identifying solutions to overcome these barriers.

In recognition of Scotland's wave and tidal potential – 25% of European tidal potential and 10% of its wave potential – we continue to invest in the infrastructure required to support Scotland's marine renewables industry. The European Marine Energy Centre (EMEC) has received around £30m of public funding to allow it to support the testing and development of both wave and tidal devices within Scottish waters.

WALES

In March 2012 the Welsh Government published **Energy Wales: A Low Carbon Transition** which sets out our ambition to create a low carbon economy that delivers jobs; long term wealth and supports our communities. Marine Energy has been identified as one of the areas of greatest potential to position Wales at the forefront of key innovation, research and development.

An Energy Programme has been established to drive forward the ambitions set out in Energy Wales.

NORTHERN IRELAND

In October 2012, The Crown Estate announced the award of development rights for two 100MW tidal projects in the first Offshore Renewable Energy Leasing Round held in Northern Ireland waters. It is expected that these projects will contribute to the Northern Ireland target of 40% renewable electricity consumption by 2020.

Support Initiatives and Market Stimulation Incentives

The main market mechanism for the support of renewable energy in the UK is the Renewables Obligation (RO). A review of the RO concluded in July 2012 in which 5 ROCs was confirmed for wave and tidal stream energy up to 30MW project cap for deployment in the period from April 2013 to 2017.Beyond 2017, it is the intention that marine technologies will continue to be supported via the proposed FiT (feed-in tariff) with a *Contract for Difference (CfD)* support mechanism introduced under the Electricity Market Reform (EMR). This should provide greater clarity and long-term vision for investors. The initial CfD price setting process for renewables will be similar to the most recent Renewables Obligation Banding Review, and much of the same data will be used to ensure broad coherence between the two schemes. However, there are a few areas where additional information may now be available or is relevant. For example, a focused complementary Call for Evidence was published in October which can be viewed on the National Grid website (**http://www.nationalgrid.com/uk/Electricity/Electricity+Market+Reform/index.htm**). An EMR subgroup from the MEPB was set up to feed into the process, ensure that the concerns of the sector were taken into consideration, and provide evidence relevant to the setting of the strike price.

Competition for the Marine Energy Array Demonstrator (MEAD) scheme was launched in April 2012 and closed in June. The scheme will provide £20 million capital grant towards the demonstration of the first wave and tidal arrays.

(**http://www.decc.gov.uk/en/content/cms/meeting_energy/wave_tidal/funding/mead/mead.aspx**). Awards are expected to be announced in the coming weeks.

SCOTLAND

To accelerate the drive towards commercialisation of the marine renewables industry in Scotland, in June 2012, the Scottish Government announced further funding through an £18 million Marine Renewables Commercialisation Fund (MRCF) to support the deployment of the first pre-commercial arrays in Scotland. Funding for the projects will be awarded in 2013.

In October 2012, the First Minister launched the Renewable Energy Investment Fund (REIF). £103m has been allocated to help promote the use of energy from renewable sources by supporting projects that:

- Accelerate the growth of the marine renewable energy sector in Scotland;
- Increase community ownership of renewable energy projects in Scotland; and
- Provide for district heating networks that utilise renewable heat technologies

NORTHERN IRELAND

Invest NI, DETI's economic development body, is working with RegenSW, Scottish Highland and Islands and Renewable UK to develop a UK-wide supply chain model for wave and tidal energy based on The Crown Estate supply chain model for offshore wind energy. The model includes activities in all areas of wave and tidal energy technology and deployment. It has been agreed to launch it in Spring 2013. The supply chain will include companies from all of UK.

Main Public Funding Mechanisms

The first port of call for enquiries about funding and other opportunities for marine energy and other renewables is the Energy Generation and Supply Knowledge Transfer Network (https://connect.innovateuk.org/web/energyktn). However, brief summaries of some of the organisations that support innovation at its different stages are given below:

- the Research Councils UK Energy Programme provides funding for basic strategic and applied research into a wide range of technology areas: http://www.rcukenergy.org.uk/

- the Technology Strategy Board supports medium-size research and development projects using technology-specific research calls: http://www.innovateuk.org/
- the Energy Technologies Institute is a public-private partnership that invests in developing full-system solutions to long term energy challenges: http://www.eti.co.uk/
- the Carbon Trust offers a wide range of support for low carbon innovation mainly in the pre-market arena: http://www.carbontrust.co.uk/Pages/Default.aspx

SCOTLAND

Scotland's enterprise bodies – Scottish Enterprise and Highlands and Island Enterprise – and its trade and investment arm, Scottish Development International, are the key contacts within Scotland to support the development and growth of Scotland's marine renewables industry. Links to the organisations are listed below:

- Scottish Enterprise provides support for businesses, and can help them to take advantage of the many opportunities presented by the energy industry in Scotland. - http://www.scottish-enterprise.com/your-sector/energy.aspx
- Highlands and Islands Enterprise is deeply involved in creating the next generation of renewable energy within the Highlands and Islands and supporting the marine renewables industry - http://www.hi-energy.org.uk/Renewables/Renewables.htm
- Scottish Development International offers support to industries looking to invest within Scotland's marine renewables industry - http://www.sdi.co.uk/invest-in-scotland.aspx

In addition to the MRCF as mentioned earlier, Scotland continues to provide significant support for the development and deployment of wave and tidal energy projects in Scotland. The four projects who receiving support through the £13 million WATERS are making good progress towards the completion of their projects, with many due for completion in early 2013

WALES

The main source for large funding in Wales, both revenue and capital, is via the Convergence & Competitiveness Fund administered by the Welsh European Funding Office (WEFO) on behalf of the Welsh Government. The Welsh Government is in discussion with the EU Commission to consider a structural fund programme post 2013 and how it might support the sector.

Relevant Legislation and Regulation

In October 2012, Marine Scotland published a licensing manual which is aimed at providing information on the planning regulations. This document is intended to provide developers with relevant information to progress their application for licences in an efficient and effective manner. A copy of the document can be accessed at **http://www.scotland.gov.uk/Resource/0040/00405806.pdf.**

The Marine Management Organisation (MMO) continue to facilitate dialogue between regulators, statutory consultees and industry.

Relevant documents released

UK

- Outcome RO Banding Review: http://www.decc.gov.uk/en/content/cms/meeting_energy/renewable_ener/renew_obs/renew_obs.aspx
- Technology Innovation Needs Assessment (TINA) for the Marine energy sector: http://www.lowcarboninnovation.co.uk/working_together/technology_focus_areas/marine/.
- The Marine Energy Array Demonstrator (MEAD) scheme: http://www.decc.gov.uk/en/content/cms/meeting_energy/wave_tidal/funding/mead/mead.aspx.
- The Crown Estate - Wave and Tidal Resource: http://www.thecrownestate.co.uk/news-media/news/2012/new-report-shows-extent-of-uk-wave-and-tidal-resources/.
- South West Marine Energy Park (SWMEP): http://www.regensw.co.uk/projects/offshore-renewables/marine-energy-/marine-energy-parks.

SCOTLAND

- Scottish Renewable Energy Investment Fund (REIF): http://www.scottish-enterprise.com/fund-your-business/scottish-investment-bank/renewable-energy-investment-fund.aspx.
- Scottish Government Marine Renewables Action Plan: http://www.scotland.gov.uk/Topics/Business-Industry/Energy/MarineAP.
- Scottish Government response to RO Banding Review: http://www.scotland.gov.uk/Topics/Business-Industry/Energy/Obligation-12-13/ROReview11-12Response.

WALES

- Energy Wales: A Low carbon Transition (2012): http://wales.gov.uk/topics/environmentcountryside/energy/energywales/?lang=en.
- Planning Policy Wales (2012): http://wales.gov.uk/topics/planning/policy/ppw/?lang=en.

NORTHERN IRELAND

- In August 2012 DETI published the NI Government response to the consultation on proposed changes to the Northern Ireland Renewables Obligation in 2013 which included the provision for 5 ROCs for wave and tidal projects to 2017, in line with the rest of the UK
- DETNI Marine Renewables Action Plan: http://www.detini.gov.uk/ni_offshore_renewable_energy_strategic_action_plan_2012-2020__march_2012_.pdf.

RESEARCH & DEVELOPMENT

Government Funded R&D

To accelerate development of marine energy, the UK provides public funding innovation in partnership with industry.

The Low Carbon Innovation Co-ordination Group brings together the major public-sector backed funders of low carbon innovation in the UK. Its core members include DECC, BIS, Carbon Trust, Energy Technologies Institute, Technology Strategy Board, the Engineering and Physical Sciences Research Council, the Scottish Government and Scottish Enterprise. Several other organisations, including the other Devolved Administrations, have recently joined as associate members.

The group's aims are to maximise the impact of UK public sector funding for low carbon energy, in order to:

- Deliver affordable, secure, sustainable energy for the UK;
- Deliver UK economic growth; and
- Develop UK's capabilities, knowledge and skills.

The group has been working together on a number of workstreams including the **Technology Innovation Needs Assessment (TINA)** project. This project aims to identify and value the key innovation needs of specific low carbon technology families, including marine, to inform the prioritisation of public sector investment in low carbon innovation.

The LCICG worked with representatives from the marine industry to ensure that the most robust data possible was fed into the TINA process.

Below are details of each organisation's programmes for marine.

Research Councils UK Energy Programme

The Research Councils UK Energy Programme aims to position the UK to meet its energy and environmental targets and policy goals through world-class research and training. The Energy Programme is investing more than £530 million in research and skills to pioneer a low carbon future. This builds on an investment of £360 million over the past 5 years.

Supergen

Work by **Supergen Marine** consortium continues (Phase 3 funding confirmed for further 5 years). It is conducting world-class fundamental and applied research that assists the marine energy sector to accelerate deployment and provide the highest quality of doctoral training.

Technology Strategy Board (TSB)

In 2012, the Technology Strategy Board, in partnership with Scottish Enterprise and the Natural Environment Research Council (NERC), ran a competition for collaborative R&D projects aiming to solve common challenges to deploying first arrays of wave and tidal devices. This competition, called "Marine Energy – Supporting Array Technologies", sought proposals that addressed themes such as: tidal array cabling, subsea electrical hubs, installation and maintenance vessels for tidal arrays, navigation and collision avoidance technologies and anti-fouling & corrosion methods. Seven projects were awarded a total of £6.5m of grants via this competition. A key aim of the programme was to share knowledge from this programme, and a first dissemination event was held in October 2012 to present the aims of these projects to the industry. The presentations made by the projects can be found at https://connect.innovateuk.org/web/marine-energy-supporting-array-technologies.

Energy Technologies Institute (ETI)

The ETI which is a joint industry Government partnership, makes targeted commercial investments in projects covering heat, power, transport, and their supporting infrastructure across nine programme areas – offshore wind, marine energy, distributed energy, buildings, energy storage and distribution, carbon capture and storage, transport, bioenergy and smart systems and heat.

The ETI launched a project in May 2012 to identify ways of providing a cost effective deployment of tidal stream technologies at commercial scale in UK waters. The Tidal Energy Converter (TEC) System Demonstrator project will adopt a system and through-life approach to identify, develop and prove the best routes and supply-chain options to commercially viable tidal stream technologies when deployed at array scale. The project, awarded to a team led by Atlantis Resources Corporation, will run over two phases, with funding released in stages according to the progress achieved.

The ETI's ReDAPT (Reliable Data Acquisition Platform for Tidal) and will soon start testing a 1MW TGL horizontal axis tidal turbine in coming weeks

Other ETI marine projects include:

- The **PerAWAT** (Performance Assessment of Wave and Tidal Array Systems) project, which has established and will validate in 2013 numerical models to predict the hydrodynamic performance of wave & tidal energy converters operating in arrays.
- The Tidal Resource Modelling project which has developed a hydrodynamic numerical which will be made available to the public in 2013 under the commercial name SMART Tide and will be accessible through a web interface via a Fee-For-Service managed by HR Wallingford.

SCOTLAND

The £13 million WATERS programme is ongoing. Further investment through WATERS 2 was announced in February 2012, with awards issued to successful developers in August 2012. Five marine developers were awarded a total of £7.9m to further develop and test new wave and tidal devices within Scottish Waters. This funding will also enable Scottish Developers and supply chain firms to capture an increased share of the growing international marine energy market which will help to boost Scotland's economy.

WALES

Marine Energy Infrastructure Study

Building on the MRESF, the Assembly Government commissioned a Marine Energy Infrastructure Study with Halcrow Group Ltd. The study has helped Wales to understand the infrastructure needs of the industry and identify specific sites suitable for deployments – from prototype to commercial scale.

The Study has produced a series of recommendations to help move the industry forward in Wales. The Study is due for publication in December 2012.

Low Carbon Research Institute – Marine Energy Research Group

The Low Carbon Research Institute (LCRI) has been set up to unite and promote energy research in Wales to help deliver a low carbon future. £7m has been set aside for marine energy research and this is managed by the Marine Energy Research Group (MERG) based at Swansea University. The organisation of the research work has been specifically designed to answer environmental and engineering concerns, and supply stakeholders with the information required to reduce risk and instill confidence in the industry.

Current research themes include the interaction of tidal turbine rotor blades with combined tide, wave and turbulent flows; marine vessel survey of high energy wave and tidal sites; CFD modeling of wave machines, tidal turbines, arrays, wakes, scour and deposition; environmental impact analysis of wave and tidal energy sites. The group has a strong role in the support of early stage device developers and the supply chain, together with public awareness and dissemination activities.

Sustainable Expansion of the Applied Coastal and Marine Sectors

Bangor University's Sustainable Expansion of the Applied Coastal and Marine Sectors (SEACAMS) project received funding in 2010 from the European Regional Development Fund through the Welsh Assembly Government. SEACAMS will promote the integration of research and business opportunities in the marine sector, to expand it at a time when there are many environmental and socio-economic challenges related to climate change and enormous opportunities for research and commercial activity in the environmental sector. SEACAMS fosters new collaborative links with industrial partners who wish to exploit new opportunities in these areas.

NORTHERN IRELAND

A Centre for Advanced Sustainable Energy has been set up in Queen's University Belfast to facilitate business led research into sustainable Energy Technologies including wave and tidal technologies. The centre is working with Northern Ireland and international companies in a number of projects including tidal testing techniques. A Centre for Advanced Engineering and Composites has been set up attached to Bombardier Aerospace to facilitate business led research into, amongst other advanced engineering, the development of composites which will include manufacture of components for renewable technologies.

Participation in Collaborative International Projects

The UK is a member of the EU Member State Ocean Energy Interest Group (9 Member States). In November 2011, a report published in collaboration with the European Ocean Energy Association "Towards European industrial leadership in Ocean Energy in 2020", calling for funding and support from the EU Commission to drive forward marine energy. The report was a high level statement of our collective willingness to work together and cooperate in this technology area and also of our keenness to form a strategic partnership with the European Commission, to achieve a strong European ocean energy industry and capability to secure low carbon, jobs, skills and growth. The Interest Group has since submitted an agreed response to the recent Commission consultation on Ocean Energy and is currently working on a proposal for European Commission funding of an EU Ocean Energy ERA-NET to facilitate further development of collaboration between Member States. The ORECCA (Offshore Renewable Energy Conversion Platform Coordination Action) Project is an EU FP7 funded collaborative project.

Awards for the European Commission NER 300 funding to support the deployment of early stage commercial arrays is anticipated by the end of 2012. Two Scottish-based tidal stream bids were shortlisted for this award.

SCOTLAND

Scotland continue to work with colleagues throughout the UK and across Europe through their membership on the British-Irish Council (BIC) and the leadership they provide in taking forward the Marine Energy Workstream and through their membership of the EU Ocean Interest Energy Group in which they support the work to raise the profile and potential of ocean energy within the EU.

WALES

The main source for large funding, both revenue and capital, is via the EU Convergence & Competitiveness Fund administered by the Welsh European Funding Office (WEFO). The Welsh Government are engaged with WEFO and the European Commission to consider a structural fund programme post 2013 and how that might support the marine energy sector.

NORTHERN IRELAND

Invest NI working with the Marine Institute in ROI in the development of ICT with SMEs and International Companies in the Smart Ocean initiative.

TECHNOLOGY DEMONSTRATION

Operational Ocean Energy Projects

At EMEC:

- Atlantis Resource 1MW tidal device (moved to Narec in May 2012 for further testing)
- Pelamis P2 750 kW wave device (Commissioned by Eon) installed
- Pelamis P2 750 kW wave device (Commissioned by Scottish Power Renewables) installed
- Aquamarine Power Limited – Oyster 800 Stage 2 installed
- Wello Oy Penguin 500 kW wave converter installed
- Open Hydro – 250kW turbine deployed
- Tidal Generation Ltd 500kW tidal turbine deployed
- Scotrenewables SR250 floating tidal turbine deployed
- Andritz Hammerfest 1MW tidal turbine deployed

At other locations:

- Atlantis Resources Corporation AR1000 1 MW tidal turbine at NaREC
- Fred Olsen "BOLT" Lifesaver (Falmouth Bay) – deployed at FabTest since spring 2012.
- Neptune Porteus 500kW tidal device in the Humber Estuary since 2011
- MCT/ SeaGen 1.2MW tidal device (Strangford Lough, Northern Ireland) - deployed and operational since 2008
- Limpet Oscillating Column 500kW (Islay, SW Scotland) - deployed and operational since 2001
- Pulse Tidal (mouth of the River Humber) - deployed their 100kW "Pulse-Stream 100" in 2009.

New Developments

In October 2012, Alstom announced the acquisition of Tidal Generation Limited (TGL) from Rolls Royce.

Results from the Crown Estate individual scheme leasing process in 2012 were:

- Lease with Voith Hydro Wavegen for its Siadar project in the Western Isle.
- Tidal Energy awarded rights for a project at St David's head in Pembrokeshire, Devon.
- Pulse Tidal awarded rights to develop a site off at Lynmouth in Devon
- Lease agreed for a test facility, Solent Ocean Energy Centre, near St. Catherine's Point in the Isle of Wight.
- Lease agreement with Scottish company Scotrenewables Tidal Power to develop a 30MW tidal stream array at Lashy Sound, Orkney Islands.
- Minesto, a Swedish technology developer, secured lease agreement to deploy a 3kW Deep Green Ocean Kite tidal device in Strangford Lough, NI.

In the Northern Ireland (NI) offshore renewables leasing round for October 2012, agreements include:

- Lease with Tidal Ventures Limited (Open Hydro Group and Bord Gais) for 100MW tidal scheme at Torr Head.
- Lease with a consortium comprising Cork based DP Marine Energy Limited and the Belgian marine engineering company DEME Blue Energy for their 100 MW tidal stream energy project off Fair Head.

There are still some interest by private consortium groups in harnessing the power from the Severn estuary by means of a tidal barrage. In summer 2012, a newly formed Hafren Power Consortium (formerly Corlan Hafren) confirm to the UK Government their outline proposal for a Severn Barrage. The proposal will need to be further developed and demonstrate strong evidence that it is viable against the criteria of value for money, economic benefits, energy saving and environmental impact mitigation before the UK Government can consider its value. In the light of recent interest in the Severn Barrage, the Energy and Climate Change (ECC) Committee launched an enquiry with a call for evidence on the proposed Severn Barrage on 30 October (http://www.parliament.uk/business/committees/committees-a-z/commons-select/energy-and-climate-change-committee/news/severn-barrage-call-for-ev/). The ECC enquiry is expected to conclude early in the new year.

In November RegenSW published a document on alternatives for harnessing energy from the Bristol Channel/Severn Estuary (http://www.regensw.co.uk/news/2012/11/27/media-release---bristol-channel-has-massive-renewable-energy-potential) suggesting a combination of lagoons and tidal stream devices.

Planned Deployment:

- TGL (ReDAPT) 1MW tidal device (to be deployed in Dec 2012)
- Tidal Electric Limited DeltaStream 1.2MW tidal device at Ramsey Sound, Pembrokeshire in Wales to be deployed in 2013
- AWS Ocean Energy AWS-III 1.25MW wave device (In planning)
- Seatricity wave energy converter to be deployed at EMEC
- Bluewater /Ponte di Archimede 1MW device to be deployed at EMEC around 2013/14
- Marine Current Turbine (MCT) have plans to deploy a 10MW pre-commercial array at Skerries, Anglesey for 2014.
- MCT plans to deploy 8MW tidal farm at Kyle Rhea in Scotland by 2014
- Minesto to deploy 3kW Deep Green Ocean Kite in Strangford Lough, NI (to be deployed).
- Voith Hydro HyTide1000-16 1MW (to be deployed).
- Voith Wavegen 4MW wave device, Siadar, Scotland (to be deployed).
- Kawasaki Heavy Industries 1MW tidal turbine to be deployed around 2014/15 at EMEC.
- Pulse Tidal to deploy 1.2MW device with grid connection off Lynmouth starting in 2014.
- Joint project between Pelamis and Aegir Vattenfall for a 10MW wave farm in the Shetland in Scotland to commence in 2016.
- Scottish Renewables to build a 10MW tidal array scheme using Andritz Hammerfest 1000 tidal turbines in the Sound of Islay between the Scottish island of Islay and Jura. First installation in 2013 with full project running by 2015.
- Meygen continue development on their planned 85MW Phase 1 deployment in the Inner Sound, Scotland. This will be phased in a 20MW followed by a 65MW deployment (timings tbc).

JAPAN

Yasuyuki Ikegami
Institute of Ocean Energy, Saga University

RESEARCH & DEVELOPMENT

Government Funded R&D

Ocean energy technological research and development has been carried out as a national project for the period 2011-2015 with a total funding of approximately 7.8 billion yen provided by the **New Energy and Industrial Technology Development Organization (NEDO)**. Under this project, two basic themes are broadly covered: verification research and technology development research.

In year 2011, verification research theme included feasibility study of wave power generation conducted by three parties, and feasibility studies of current power generation conducted by one party. Verification research under real sea conditions is planned after year 2014.

In year 2011, technology development included research on tidal current power generation and ocean thermal energy conversion. Further, new topics have been added to the wave power and tidal power research. Verification research on the newly established topics has been conducted by one party, while two parties have conducted technology development research on the newly established tidal power topic.

At present, there are ten groups in total carrying out research and development for the practical use of the ocean energy; one party is dedicated to ocean thermal energy conversion, one party is dedicated to ocean current power generation, four parties are dedicated to tidal power generation and four parties are dedicated to wave power generation.

Verification experiments have been conducted at real sea conditions with the aim of realizing a power generation cost of 40JPY/kWh in practical use by 2015. Resource assessment and experimental tests performed in wave tanks have been carried out during the FS period. Based on the obtained results, NEDO will conduct a stage-gate evaluation in the first quarter of 2013, and identify the parties that will be entrusted to conduct verification research in real sea. Parties passing the stage-gate evaluation are expected to perform environmental impact assessment studies and manufacture the power generation equipment necessary for process demonstration during the fiscal year 2013. Construction and demonstration in real sea is to be done in 2014.

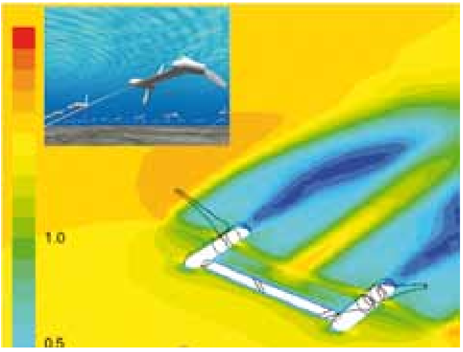
Wave power generation experiment conducted in a wave tank (1/16) -Mitsui Engineering & Shipbuilding-

Tidal power generation experiment conducted in a wave tank (1/10) -Kawasaki Heavy Industries, Ltd-

Technology Development

Technology development research is concerned with the development of core technologies aiming to reduce the power generation cost to 20 JPY/kWh by 2020.

Simulation and verification experiments of the various components conducted in wave tanks have been performed during the period 2011-2012. Baseline design and cost evaluation of the various power generation systems is planned in 2013 and later.



Simulation of the ocean current power generation (IHI, Toshiba, Mitsui Global Strategic Studies Institute, University of Tokyo)

30kW OTEC system (Saga University)

IRELAND

Eoin Sweeney
Sustainable Energy Authority of Ireland

INTRODUCTION

The Ocean Energy Strategy was initiated in 2006, aimed at developing the wave and tidal sector. Since then, there has been ongoing work to create a supportive policy framework, develop infrastructure, support industry development and build research capacity to create a favourable developmental environment. To this end, the Ocean Energy Development Unit (OEDU) was set up in the Sustainable Energy Authority of Ireland (SEAI) in 2008 to take the sector forward, through a comprehensive suite of activities.
In 2011 and 2012, the financial crisis, together with the slower than expected rate of development and deployment of OE technologies, has led to a relative cutback in funding for the sector.

OCEAN ENERGY POLICY

Strategy and National Targets

Ireland's Offshore Renewable Energy Development Plan (OREDP) continues to be developed by the Department of Communications, Energy & Natural Resources. The draft OREDP is publicly available on the Department's and SEAI's websites. It describes the current situation in Ireland on offshore wind, wave and tidal energy. It explains how policy is in development in this sector and some of the factors that are likely to affect policy as it develops.

The draft Plan notes Ireland's involvement in many initiatives and its openness, at a strategic level, to considering the possibilities and opportunities offered by offshore renewable energy. The draft Plan considers low, medium and high scenarios for the development of offshore wind, wave and tidal energy in the period to 2030. The Strategic Environmental Assessment has been undertaken on these three scenarios which include up to 4,500MW of offshore wind and 1,500MW of wave and tidal energy in the period up to 2030.
Ireland has been set a binding renewable energy target under Directive 2009/28/EC and has published a National Renewable Energy Action Plan (NREAP) setting out how the target for 2020 is to be achieved. In the NREAP, Ireland states in its modelled electricity scenario that it expects 555MW of offshore wind to be contributing to its 2020 target as well as 75MW of wave and tidal generated power.
The Renewable Energy Directive provides co-operation mechanisms for Member States to trade renewable energy in the period to 2020, if they are able to exceed their national target. The government is involved in bilateral discussions with neighbouring countries on the use of these mechanisms for the export of renewably generated electricity. A study on the cost benefits of Ireland engaging in the co-operation mechanisms under the Directive was completed in 2012.

An **Ocean Energy Roadmap**, formulated by SEAI, was published in 2010. It is designed to initiate a debate about the pathway to 2050 for ocean energy in Ireland... The key features of the Roadmap are:

- The Strategic Environmental Assessment reports that, potentially, 29GW of ocean energy capacity can be installed without likely significant adverse effects on the environment.
- Employment opportunities of up to 70,000.
- Cumulative economic benefit up to €12 billion by 2030 and up to €120 billion by 2050 from factors such as electricity generated, emissions reductions, security of supply, regional development & knowledge created.
- National energy security is significantly enhanced.

There will be ongoing testing of the assumptions and projections in this Roadmap

Support Initiatives and Market Stimulation Incentives

In 2009, the government announced a Refit tariff of €220 MW, for wave and tidal energy. This has not yet been activated and the Marine Renewable Industry Association (MRIA) has proposed a more precisely structured mechanism to support the sector in its growth phase.

Main Public Funding Mechanisms

The principal funding mechanism for the OE sector is the Prototype Development fund, administered by the Ocean Energy Development Unit. This supports industry-led projects for the following types of activities:

- Projects to develop and test wave and tidal energy capture devices and systems;
- Independent monitoring of projects/technologies;
- 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.

Other significant funding for university/industry research projects and for the commercialisation of successful early-stage companies is provided by **Enterprise Ireland**, the indigenous industry support agency.

Relevant Legislation and Regulation

Offshore marine renewable energy projects currently fall within the jurisdiction of the Foreshore Acts 1933 to 2009. The Foreshore Acts apply to the seabed and shore below the line of high water of ordinary or medium tides and outwards to the 12 nautical miles limit of the territorial seas (22.22 kilometres). Jurisdiction beyond this limit is determined by the UN Convention on the Law of the Sea.

Since 2010, the Department of Environment, Community and Local Government (DECLG) has been working on the streamlining and modernising of the consent process for foreshore developments, with particular emphasis on renewable energy projects. It is intended that the reforms will deliver a plan-led policy framework for the approval of activities and developments in the marine environment, a single consent process for project approval as well as greater certainty of timeframes. Mandatory pre-application consultations, transparent assessment of environmental impacts and full public participation are also planned. A new legislative Bill is now expected in 2013 or early 2014.

DECLG is also working with other relevant Departments and agencies on the development of a marine spatial planning framework, providing for the strategic development of the foreshore while managing competing, and often conflicting, sectoral demands. In 2012 extensive new Special Areas of Conservation were announced which will have implications for the development of marine renewable energy projects.

Relevant documents released

A full list of publications relevant to the OE sector is available at http://www.seai.ie/Renewables/Ocean_Energy/Ocean_Energy_Information_Research/Ocean_Energy_Publications/

In 2012 a new document was released:

- A Study of the Supply Chain Requirements and Irish Company Capability in the Offshore Wind, Wave and Tidal Energy Sector

A study was also commissioned on the options for offshore grid on the west coast of Ireland. This will be completed in 2013.

RESEARCH & DEVELOPMENT

Government Funded R&D

The OEDU is continuing work on the establishment of a full scale grid connected wave energy test facility off County Mayo. It will be connected to the national electricity grid and will provide facilities for the testing of full scale devices in development by Irish and multi-national companies and will be able to accommodate up to 3 devices at any one time. A grid offer is in place, a formal lease application has been made and is currently awaited. It is planned to commence construction of the sub-station in 2013.

Full scale grid connected wave energy test facility off County Mayo

SEAI, in partnership with the Marine Institute, continued to operate the wave energy 1/4scale test site in **Galway Bay**. Work commenced, aimed at enhancing the facility by providing power and bandwidth to the site, in conjunction with the SmartBay initiative. This work will continue into 2013.
The SmartBay Pilot Project in Galway Bay is designed to be a research, test and demonstration platform, and innovation test bed, for new ocean technologies developed by research institutes and companies in the fields of communications, informatics, instrumentation and sensors. In 2012 an operating company – SmartBay Ltd - was established to develop and manage the research infrastructure in Galway Bay.

The **Hydraulics and Maritime Research Centre in University College Cork (UCC)** is the principal ocean energy research facility in Ireland, with special interest in ocean energy research and coastal engineering. Major enhancement of the facility as the National Ocean Test Facility is now in the design phase, as a key part of the Irish Maritime and Energy Resource Cluster (IMERC), with financial support from the Higher Education Authority, industry and the OEDU. Construction will commence in 2013. Key areas of research expertise include:

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

Projects funded by **Enterprise Ireland** at HMRC include SeaGrid, a study on grid integration software and services of ocean energy which has grown from Irish participation in the IEA OES Annex on grid integration and NAVITAS, a study on Economic Assessment of Ocean energy systems, farms and projects.
The **University of Limerick** has a Robotics group with special interest in applications in the marine renewables area.

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

The Department of Electronic Engineering in th**e National University of Ireland, Maynooth** has a dedicated Wave Energy Group working in the areas of

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

Industry Funded R&D

All of the research and demonstration activities involve an element of match-funding from industry.

SEAI and Enterprise Ireland are funding Ocean Energy device developers at various stages and are also funding development of new components and supply chain elements that will ultimately assist all of the industry. Examples of projects funded in the period 2010-2012 include:

- Benson Engineering – Device and sea water component pump
- Limerick Wave – Power take off
- Carnegie Wave – Site assessment
- Open Hydro – Technology enhancement
- Jospa – Device development
- Waveberg – device development
- Key Engineering Services – systems devlopment
- Cyan Wave – device development
- Wave Energy Ireland – combined device development
- Wavebob – technology enhancement
- Ocean Energy Ltd – device development
- Bluepower Energy – power take off
- Technology from ideas – supply chain and components
- Seapower – device and components
- Houston engineering – power take off
- IBM Inc – Acoustic monitoring of WECs

Participation in Collaborative International Projects

MARINET - UCC co-ordinates the EU FP7 MaRINET (Marine Renewables Infrastructure Network for Energy Technologies) project. MARINET (Marine Renewables Infrastructure Network) is a new network of research centres which aims to accelerate the development of marine renewable energy (wave, tidal & offshore-wind) by bringing together world-class testing facilities to offer EU-funded testing and to coordinate focussed R&D. Many European marine renewable energy test centres have formed this network in order to work together to offer their unique capabilities and services in a coordinated way, essentially providing a one-stop-shop for marine renewable energy research and testing in Europe and farther afield (e.g. Brazil). The European Commission has supported this initiative by way of funding through the FP7 programme. This enables MARINET partners to offer periods of access to their facilities at no cost to users. Access is open to all potential users who wish to avail of these facilities – research groups, companies, SMEs etc. As well as offering test facility access, MARINET will also implement common standards for testing, conduct research to improve testing capabilities and provide training at various facilities in the network in order to enhance expertise in the industry. Access is available to 42 facilities from 28 network partners spread across 11 EU countries and 1 International Cooperation Partner Country (Brazil). The initiative runs for four years until 2015, with at least four calls for access applications. In total, over 700 weeks of access is available to an estimated 300 projects and 800 external users. For further information see www.fp7-marinet.eu

SOWFIA – Streamlining Ocean Wave Farms Impact Assessment – Multi-disciplinary multi- partner EU EACI IEE project coordinated by University of Plymouth with objective to develop and improve tools and methods for environmental and social impact assessment of wave farms. UCC is a partner and Work Package Leader.

IEC TC114 – Ireland has a mirror committee and contributes experts to TC114 development of standards and guidelines in ocean energy

OES – Ireland contributes directly to IEA in terms of EXCO but has also been a key contributor to many of the collaborative annexes

International Smart Ocean Graduate Education Initiative – Ireland has a graduate programme co-funded by members of the SmartOcean group which has a mix of Irish and International entities. First round of PhDs starting

Ireland, through HMRC, also participates in the **European Energy Research Alliance** research network, EERA, and is participating in the preparation of an ERA-Net proposal, to deepen collaboration between funding programmes in European countries for OE.

Key Statistical Information - level of public and private investment on R&D

Public expenditure on R&D in 2012 is estimated to be €2.5m
Private investment on R&D in 2012 is estimated to be €4m

TECHNOLOGY DEMONSTRATION

New Developments

UCC Beaufort and IMERC

As mentioned in section 3.1 DCENR, IDA, PRTLI, SEAI-OEDU, DAFM, UCC and Bord Gais are funding a new 4,500 sq.m. building to house the National Ocean Test Facility. This UCC Building, designated "Beaufort Research", is a €16.5m cornerstone and flagship facility housed within the Irish Maritime and Energy Resource Cluster **(IMERC)**. IMERC is a joint venture between UCC, Cork Institute of Technology and the Irish Naval Service.

Westwave 5 MW Demonstration Project

The WestWave project aims to develop the first wave energy project in Ireland by 2015 by generating 5MW of electricity from the plentiful wave energy resource off the west coast of Ireland. WestWave is a collaborative project being led by ESB International (ESBI) in conjunction with a number of wave energy technology partners including Irish technology developers Wavebob and Ocean Energy and Scottish technology developers Aquamarine Power and Pelamis Wave Power. ESBI, with support from the Sustainable Authority of Ireland (SEAI), is building upon previous supply chain analyses of marine energy to focus specifically upon the requirements of the WestWave Project. Within this supply chain study the project team has assessed, along with four leading technology developers, the requirements to deliver the WestWave project within the timeframe required. The project is currently undergoing feasibility assessment processes involving the European Investment Bank, the Department of communications, Energy and Natural Resources and ESBI. This project received funding approval in December 2012 from the EU NER300 Programme.

Lease awards Northern Ireland

In 2012 2 companies were awarded rights to develop the tidal renewable energy resource in Northern Ireland. These are:

- Tidal Ventures Limited for the 100 MW tidal opportunity at Torr Head: a joint venture between Open Hydro Group, a designer and manufacturer of tidal turbines, and Bord Gáis Energy one of Ireland's leading energy providers.
- DP Marine Energy Limited with DEME Blue Energy for their 100 MW tidal stream energy project off Fair Head: this project is a consortium comprising Cork based DP Marine Energy Limited and the Belgian marine engineering company DEME Blue Energy.

CANADA

Tracey Kutney[1 2], Jonathan Brady[2] and Chris Campbell[3]
[1]CanmetENERGY, [2]Natural Resources Canada, [3]Marine Renewables Canada

INTRODUCTION

Canada has one of the largest tidal resources in the world. In 2012, Canada continued to build the enabling environment to develop its marine renewable energy sector. Activities defined in Canada's Marine Renewable Energy Roadmap, released in November 2011, were undertaken, with the sector focusing on a number of foundational initiatives critical for commercialization of this industry.

In the past year, both the federal and provincial governments continued developing supportive policies, shared infrastructure, and strategic research initiatives. The province of Nova Scotia remained the focal-point of activity for marine renewables in Canada. In May, Nova Scotia released its "Marine Renewable Energy Strategy", which articulates the province's goal of advancing marine renewable energy beyond resource prospects and technology trials, to a new phase of accelerated development that will facilitate domestic industrial growth, international exports and roughly 300 MW of grid-connected in-stream tidal current energy generated by 2030. Nova Scotia's Community Feed-In-Tariff (COMFIT) program became the first program in the world to award community-owned tidal projects, with 5 projects awarded to date. Building on the success of the COMFIT program, Nova Scotia is developing a tidal energy Feed-in-Tariff (FIT) program for Developmental Tidal Arrays and devices greater than 500 kW. This new FIT program is expected to be launched in 2013 and will apply to the fourth berth currently tendered at the Fundy Ocean Research Centre for Energy.

In September, the province of British Columbia signalled its continued interest in supporting the development of the marine renewable energy sector with the signing of a declaration of intent with Nova Scotia to collaborate on in-stream tidal energy research and policy development.

At the federal level, the Government of Canada continued to support research, development and deployment initiatives and is examining options for a policy framework to administer renewable energy projects in the federal offshore.

OCEAN ENERGY POLICY

Strategy and National Targets

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

Nova Scotia's Marine Renewable Energy Strategy outlines the Province's plan to promote innovation and research, establish a regulatory system and encourage the development of market-competitive technologies and an industrial sector. It sets targets to develop marine renewable energy legislation by 2013, the installation of 5 to 60 MW of grid-connected in-stream tidal electricity generation by 2015 and 300 MW of in-stream tidal electricity generation grid connected by 2030.

Support Initiatives and Market Stimulation Incentives

Over the last six years, Marine Renewables Canada, formerly known as the Ocean Renewable Energy Group, estimates that there has been at least $85 million in federal and provincial support to marine energy development projects.

At the provincial level, the Government of Nova Scotia launched the COMFIT program, in September 2011, to encourage the development of local renewable energy projects by: municipalities, First Nations, co-operatives, universities, local economic development corporations and non-profit groups. Under the COMFIT program, Nova Scotia allows local community groups to connect small-scale in-stream tidal devices, under 500 kW, to the electrical grid at the distribution level at a feed-in tariff price of 65.2 cents/kWh over a 20-year contract. Under the *Nova Scotia Electricity Act*, the Government of Nova Scotia established the authority to create a FIT for Developmental Tidal Arrays program - to in-stream tidal current projects, arrays or single devices greater than 500 kW, that are transmission connected. The Nova Scotia Department of Energy is currently seeking FIT pricing rates from the provincial Utility and Review Board. The Board's decision on this FIT program is expected in 2013 and will be applicable for developers answering Nova Scotia's Request for Proposals for the fourth berth at the Fundy Ocean Research Centre for Energy (FORCE), Canada's tidal-energy demonstrating facility. The winning bid for the fourth berth is expected to be announced after the FIT program is established in 2013.

Main Public Funding Mechanisms

To date, Canada's main public funding programs supporting national research, development, and demonstrations are from federal programs administered through the Office of Energy Research and Development, such as the Clean Energy Fund (CEF), the Program for Energy Research and Development (PERD) and the ecoENERGY Innovation Initiative (ecoEII). Through these programs Canada has committed approximately $37 million to marine renewable energy RD&D since 2010. In addition, Sustainable Development Technology Canada (SDTC), an arm's length foundation created by the Government of Canada, has committed approximately $13 million to develop and demonstrate projects that include in-stream tidal, river-current and wave energy technologies.

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

Nova Scotia has directly invested in the FORCE development initiative and, through the Offshore Energy Research Association of Nova Scotia (OERA), supported a number of strategic research projects in marine energy, estimated to be approximately $8 million. In addition, provincial economic development agencies and funds, in Nova Scotia, Quebec, Ontario and British Columbia, have provided at least $10 million to support projects.

Relevant Legislation and Regulation

Nova Scotia's 2012 Marine Renewable Energy Strategy, establishes a Regulatory Plan emphasizing environmental protection, stakeholder engagement and a licensing system for demonstration and commercial projects. Environmental protection elements of the Regulatory Plan call for a staged, adaptive management approach to permitting that reflects incremental deployment of tidal devices and monitoring for environmental impacts. Stakeholder engagement is expected to be formalized through a Tidal Energy Stakeholder Forum that will act as an advisory council to reflect various stakeholders' interests and inform the public of project activities, scientific data analysis and socio-economic opportunities related to tidal energy. Licensing processes for rights in the provincial offshore will complement the incremental nature of tidal energy development with a licensing process for the testing and demonstration stage, up to 15 MW, and a separate licensing process for large-scale commercial grid-connected projects up to 300 MW.

Regardless of where a marine renewable energy project is planned for development in Canada, a number of federal regulatory approvals are likely to be required. This stems from the federal government's responsibility over a number of issues in all areas of Canada, including fisheries, navigation, and certain environmental issues. Canada has robust laws governing the oceans, but like many countries around the world there is no specific legal framework designed for the governance of renewable energy activity in the federal offshore. Under the Marine Renewable Energy Enabling Measures program, Natural Resources Canada is taking a lead role towards the development of a policy framework for administrating renewable energy, including wind, wave and tidal, in the federal offshore on behalf of the Government of Canada.

Relevant documents released

- Nova Scotia Marine Renewable Energy Strategy
- International Overview of Marine Renewable Energy Regulatory Frameworks
- Pathways of Effects for Offshore Renewable Energy in Canada
- A Framework for Environmental Risk Assessment and Decision-Making for Tidal Energy Development in Canada

RESEARCH & DEVELOPMENT

Government Funded R&D

In September 2012, Natural Resources Canada committed an additional $5 million under the Clean Energy Fund program to FORCE in order to assist in supporting costs related to the development of a subsea cable-connected instrumentation platform, which will host monitoring equipment for site characterization and environmental monitoring. The total instrumentation platform project value is $10 million, with $ 5 million in additional funding coming from Encana, Ocean Networks Canada and FORCE berth holders.

In September 2012, Natural Resources Canada also committed $1 million under the ecoENERGY Innovation Initiative (ecoEII) program to Marine Renewables Canada to support Canadian industry participation in the development of international standards (IEC TC 114) and R&D activities.

FORCE, the Nova Scotia Offshore Energy Research Association (OERA) and the Fundy Energy Research Network (FERN) in Nova Scotia continue to conduct and support research activities. In 2012, Acadia University in Nova Scotia established the Acadia Tidal Energy Institute. The Institute will be focused on developing partnerships and leading multi-disciplinary research projects and other initiatives that address knowledge gaps associated with the developing tidal energy industry, such as: resource assessments; environmental monitoring and impacts; socio-economic growth; sustainable communities; and, the development and delivery of tidal energy educational programs.

Marine energy research is being conducted at the universities of Victoria, Manitoba, Acadia, Dalhousie and the College of the North Atlantic. Marine energy research activities at these universities have been growing with the work of 15 graduate students, one doctoral student, and focused research grants, as estimated by Marine Renewables Canada, of approximately $5 million in place.

Natural Resources Canada's internal CanmetENERGY Marine Energy Technology team is supporting and conducting technology-focused research. The CanmetENERGY Marine Energy Technology Team is currently engaged in marine energy research to support the development of international standards, technology advancement, resource characterization, and monitoring equipment.

The Department of Fisheries and Oceans (DFO) is leading the federal government efforts on environmental impact research. In December 2011, DFO completed its report "Pathways of Effects for Offshore Renewable Energy in Canada", which outlined the potential environmental impacts of offshore renewable energy devices. The report was presented and scientifically validated at a workshop organized by the Canadian Science Advisory Secretariat (CSAS). Participants at the CSAS workshop included academia, industry, and federal, provincial, and U.S. government representatives. This Pathways of Effects work was subsequently used to identify future research needs, and will contribute towards the development of national guidance for in-stream tidal energy activities. The report can be accessed on the DFO website and on the Tethys database (IEA OES Annex IV).

Participation in Collaborative International Projects

In September 2011, Canada and the United Kingdom endorsed the Canada-United Kingdom Joint Declaration to ensure a stronger partnership for the 21st century. As part of the Joint Declaration both governments declared an intention to mutually encourage the development of marine renewable energy technologies from pilot-scale devices to grid-connected power generation stations. In May 2012, the tenets of the UK-Canada Joint Declaration were further articulated in the Canada–UK Innovation Statement, which committed the UK and Canada to "collaboration on technology development and knowledge sharing between both countries to accelerate the development, demonstration and deployment of technologies and process to support the marine energy sector…". There have been five missions between Scottish and English government officials and Canada, as well as a marine renewable energy trade-mission, with government and industry representatives, under the auspices of the Joint Declaration. These missions explored strategic partnership opportunities and further strengthened commercialization efforts between Canada and the UK.

In February 2009, the Clean Energy Dialogue was established between Canada and the United States to enhance joint collaboration on the development of clean energy science and technologies to reduce greenhouse gases and combat climate change. In June 2012, the release of the Clean Energy Dialogue Action Plan II identified offshore renewable energy as one of the policy priorities under the Electricity Grid Working Group. As part of this initiative, Canada's Department of Natural Resources and the U.S. Department of Energy collaborated in the commissioning of a report on the marine renewable energy regulatory regimes of the following six European countries: Denmark, Germany, Ireland, the Netherlands, Portugal and the United Kingdom. The focus of this report, entitled "International Overview of Marine Renewable Energy Regulatory Frameworks", is to provide a governance and regulatory overview of each country and lessons learnt by industry and government in the administration of offshore renewable energy activities.

The Fundy Ocean Research Centre for Energy (FORCE) and the European Marine Energy Centre (EMEC) joined in a strategic relationship in 2011 with the signing of a Memorandum of Understanding. In 2012, both FORCE and EMEC continued collaborative activities in scientific and technical areas of mutual interest.

Canada had a significant presence at ICOE 2012 in Dublin, with over 25 Canadian companies participating. At ICOE 2012, it was announced that Marine Renewables Canada will host ICOE 2014 in Halifax, Nova Scotia.

TECHNOLOGY DEMONSTRATION

Operational Ocean Energy Projects

The technology developer, Renewable Energy Research (RER), reports that the 250 kW TREK turbine has been in operation since August 17th 2010 in the Saint-Lawrence River near Montreal, Quebec. As of December 2012, RER reports that it has been operating for a total of 19,130 hours, without any disruption and zero failure. RER is planning to install more turbines starting in 2013.

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

New Developments

The 500 kW (2 x 250 kW) **Canoe Pass** project in British Columbia is planning to deploy the New Energy EnCurrent generators in 2013. The project will be in a causeway of a narrow channel between Quadra and Maud Islands in British Columbia.

FORCE has completed construction of the 138 kV transmission line and the substation and electrical infrastructure. FORCE has also completed phase 1 of the subsea cable lay trials. The FORCE visitors centre received about 3,700 visitors as of November 2012.

Fundy Tidal Inc., a community-based project developer, was awarded COMFIT approvals for 5 of their projects: **Digby Gut** (1.5 MW); **Petit Passage** (500 kW) and **Grand Passage** (500 kW) which are near the mouth of the Bay of Fundy, and near Cape Breton; Grand Narrows / Barra Strait (100 kW) and; Great Bras D'Or Channel (500 kW). Currently, Fundy Tidal Inc. is undertaking resource assessment analyses, site characterization and screening-level environmental assessment work. In-stream tidal current energy converters for these projects will be chosen through a request for proposal (RFP) process.

Clean Current is preparing for early spring deployment of their new river-current turbine for initial testing and demonstration in Manitoba.

Idénergie is a new company that is developing very-small scale river-current energy converters. They have conducted initial trials with their machine in Quebec.

Verdant Power is moving forward with the CORE project in the St. Lawrence River, near Cornwall in Ontario.

Emera is understood to be advancing their tidal development plans in Nova Scotia, with the aim of contributing to the first Marine Renewable Energy Technology Roadmap target in 2016.

UNITED STATES OF AMERICA

Michael Reed
U.S. Department of Energy (DOE)

INTRODUCTION

In 2012 the U.S. ocean energy industry accomplished several significant achievements, including: multiple open water deployments, advancements in infrastructure development, initial grid connectivity, landmark power purchase agreements (PPA), and milestones in permitting and licensing. The open water deployments have provided valuable baseline performance data and in-water test experience to inform future design improvements. Furthermore, this was the first year developers (**Verdant Power, Ocean Renewable Power Company, and Ocean Power Technologies**) received hydrokinetic licenses issued by the Federal Energy Regulatory Commission (FERC), which resulted in the development of 5.55 MW of demonstration projects. Overall, there were approximately 85 active FERC-issued hydrokinetic preliminary permits in 2012, totalling roughly 14.8 GW. Throughout 2012 technology development progressed with the addition of an ocean energy technical data exchange forum (Annex V) to the International Energy Agency's Ocean Energy Systems – Implementing Agreement. Additionally, the device cost reference model efforts continued and a new collaborative initiative to develop an open source numerical modeling package (WECSim) began. The WECSim initiative will simulate power production for multiple wave energy converter architectures and is a collaborative effort among the National Renewable Energy Laboratory, Sandia National Laboratories, and other code developers. Additionally, resource assessments for ocean current, river current, and ocean thermal progressed and will be complete during late 2012 and early 2013. Environmental research and information sharing continued with the launch of the Department of Energy's (DOE) *Tethys* database and the extension of Annex IV activities, with the final report and data to be publicly released in 2013. The outlook for 2013 is optimistic, with further testing of a number of devices planned and some projects expanding to arrays and commercial-scale devices.

OCEAN ENERGY POLICY

Strategy and National Targets

This mission of the DOE Water Power Program is to research, test, evaluate, develop and demonstrate innovative technologies capable of generating renewable, environmentally responsible and cost-effective electricity from water resources. Pursuant to that mission, the Program is currently undertaking the necessary analysis to assess the opportunities associated with tapping ocean energy resources. The completion of significant advanced assessments of U.S. wave and tidal energy resources has resulted in a programmatic decision to focus technology development efforts largely on the abundant national wave energy resource. Based on these analyses, the Program has established a national marine and hydrokinetic (MHK) deployment goal of 23 GW by 2030.

The strategy of the Water Power Program is broken down into four major thrust areas:

1. Technology Advancement
2. Testing Infrastructure and Instrumentation Development
3. Resource Characterization
4. Market Barrier Identification and Removal

The 2012 DOE MHK portfolio consisted of 115 projects and represented a total Program investment of $34 million. Most of the MHK funding (80%) was directed toward major thrust areas 1 and 2.

Support Initiatives and Market Stimulation Incentives

During this past year a variety of market stimulation activities were introduced that will continue to be pursued in 2013. First, the re-authorization of the Marine Renewable Energy Promotion Act proposes: higher funding levels to DOE, the creation of a new adaptive management program, and the prioritization of a device verification program that would accelerate commercialization. Additionally, the Act includes companion tax legislation that provides a five-year tax depreciation schedule to MHK – an incentive currently available to other renewable energy technologies. Furthermore, Department of Defense appropriators and members of the Armed Services committees are collaborating to develop language that would help the U.S. Navy to formalize its MHK R&D efforts, and provide additional funding for these activities under the Navy energy program office. In addition, a number of states have authorized clean energy incentives that further support water power development. To compile these efforts, DOE maintains a Database of State Incentives for Renewables and Efficiency (DSIRE) which can be found at http://www.dsireusa.org

Main Public Funding Mechanisms

The primary means by which the U.S. federal government supports ocean energy is by providing grants to competitively-selected companies and institutions active in ocean energy R&D in the United States – much of which is funded through the DOE Wind & Water Power Program. Throughout 2012 DOE continued to support industry demonstration projects through its Technology Readiness Level Advancement Initiative as well as Advanced Water Power grants. This past year DOE issued a Funding Opportunity Announcement (FOA) for ocean energy technology, titled "In-Water Wave Energy Conversion (WEC) Device Testing Support." This FOA is particularly significant for the wave energy industry because it offers $500,000 to one project to deploy and test a buoy (point-absorber) WEC for one year at the Navy's Wave Energy Test Site (WETS) off of Marine Corps Base Hawaii in Kaneohe Bay, Oahu. On September 25, 2012 **Northwest Energy Innovations** was selected to receive the award for their Wave Energy Technology – New Zealand (WET-NZ) device.

Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) are U.S. Government programs in which federal agencies set aside a small fraction of their funding for competitions only open to small businesses. These programs help emerging MHK technologies advance along the DOE Technology Readiness Level (TRL) chain. Small businesses that win awards in these programs keep the rights to any technology developed and are encouraged to commercialize the technology. In April 2012 DOE announced that $9 million would be available to fund approximately 50 small businesses developing a variety of renewable energy technologies. Each selected project would receive a Phase I award of up to $150,000. Awardees with successful projects would also have the opportunity to compete for follow-on Phase II funding for as much as $1 million per project. Two notable projects that received 2012 SBIR/STTR funding are **FloDesign** and **Oscilla Power**.

Relevant Legislation and Regulation

In 2010 President Obama signed an Executive Order establishing a new National Ocean Council and adopting a new national ocean policy to enhance stewardship of U.S. ocean waters and the Great Lakes. In 2012 the National Ocean Council released a Draft Implementation Plan for the policy and began regional marine planning efforts in many parts of the country, which will facilitate efforts to plan for energy generation from U.S. ocean resources.

The Department of Interior's Bureau of Ocean Energy Management (BOEM) has established additional State Task Forces in Oregon and Hawaii to help identify lease blocks best suited for wave energy development and is continuing to establish similar Task Forces in other states. In addition, BOEM and FERC announced revised guidelines for MHK developers pursuing permitting and licensing on the U.S. Outer Continental Shelf. The revisions further clarify the regulatory process and help streamline the procedure for authorizing research and testing of MHK devices.

RESEARCH & DEVELOPMENT

Government Funded R&D

The goal of the DOE Water Power Program investment strategy is to compress the MHK technology development timeline to approximately 10 years. Through targeted investments and the Technology Readiness Level (TRL) process, the Program helps advance developing MHK technologies toward technological maturity. TRLs are used by numerous federal agencies and private sector companies to assess the maturity of evolving technologies. TRLs 1-4 are focused on R&D, TRLs 5-8 are focused on early technology demonstration, and TRLs 9&10 are focused on full-scale prototypes, array deployments, and commercialization.

In 2012 DOE continued its efforts to develop six computational "Reference Models" (RM) designed to establish baseline costs of energy (COE) for 6 standard MHK device designs. In this sense, a "Reference Model" primarily serves as a cost model for a reference device design. A comprehensive cost model is constructed by: (1) creating numerical models to evaluate performance and structural loads, (2) performing a reference resource site-assessment including energy intensity, and environmental siting and permitting, (3) developing a concept-level design, and (4) developing a cost and economic assessment of the technology at different deployment scales. Results will be verified and improved through subscale testing of each reference device and data-correlation with industry project deployments of real devices of similar archetype. Through this process, key cost drivers will become apparent and cost reduction pathways will be identified. The 6 chosen device types are:

RM1 – Dual Rotor Axial Tidal Current Turbine
RM2 – Dual Rotor Crossflow River Current Turbine
RM3 – WEC Point Absorber
RM4 – Ocean Current Axial Turbine
RM5 – Moored Oscillating Surge Device
RM6 – WEC Oscillating Water Column

Reports for RMs 1-3 are nearing completion and will be published in early 2013. Development of RM4 is complete and the final report is being drafted. RMs 5 and 6 are under way and will be completed by the end of 2013.

This past year DOE also completed an MHK testing infrastructure assessment for wave and current technologies to identify capability gaps, prioritize needs, estimate costs, and guide the Program's investment strategy. After performing a global survey of existing MHK testing facilities, the assessment identified the following U.S. infrastructure needs: an open water test berth, a controlled-conditions, deep-water wave tank, and an oscillating drivetrain simulator. Following the results of this study, efforts are currently underway to develop the infrastructure necessary to close these gaps. The open water test berth will be a fully energetic site for TRL 7/8 demonstration of grid connected devices and eventually arrays. The deep-water wave tank (10-20 m depth) will create a controlled, repeatable testing environment for systematic trials with 1/5th scale wave energy devices at 1 m wave heights. The drivetrain simulator for power take-off component testing will analyze rotary or linear systems based on function, power performance, and component safety.

Furthermore, the Program also launched a new collaborative initiative to develop a numerical modeling package to simulate wave energy converters (WECSim). This joint venture by the National Renewable Energy Laboratory (NREL), Sandia National Laboratory (SNL) and other code developers will produce a quick-running open source code for assessing energy capture and power performance for multiple WEC geometries in an 'operational' (non-storm) wave climate. The WECsim modeling package will be made robust and reliable through verification by comparison with other similar codes and validation using comprehensive data sets. Upon completion and validation, WECSim will be made publicly available.

In addition to technology advancement R&D activities, there were a number of advances in environmental research and information sharing in 2012. The knowledge management system *Tethys*, developed by DOE's Pacific Northwest National Laboratory (PNNL), was released in the spring of 2012 at the Global Marine Renewable Energy Conference in Washington, DC (http://mhk.pnnl.gov/wiki/index.php/Tethys_Home). *Tethys* is a database and knowledge management system that provides access to information and data pertaining to the potential environmental effects of MHK and offshore wind development. *Tethys* also hosts data from Annex IV that will be available in early 2013.

Many U.S. MHK environmental studies were completed in 2012, including a number of studies funded by DOE. The Electric Power Research Institute (EPRI) released reports on fish blade strike experiments, which evaluated fish survival and injury rates following passage through a flume containing a hydrokinetic turbine. This research demonstrated that fish were largely able to avoid the turbines, and survival rates were very high. PNNL and SNL completed an analysis to assess the mechanics and biological consequences of blade strike on a Southern Resident Killer Whale by an **OpenHydro** turbine blade and found that adult whales are not likely to experience significant tissue injury, even in a worst case scenario.

PNNL completed two studies to assess the effects of electromagnetic field (EMF) and tidal turbine noise exposure on a variety of marine species. SNL finished a multi-year effort to modify an Environmental Fluid Dynamics Code (EFDC) model to predict impacts to system hydrodynamics and sediment transport from the operation of a tidal turbine; this tool is now available for regulator and developer use. Argonne National Laboratory also completed a project to develop conceptual models that assess potential MHK technology impacts to biological resources. Final reports from these studies and others will be available on PNNL's *Tethys* database: http://mhk.pnnl.gov/wiki/index.php/Browse_Knowledge_Base. Other studies funded jointly by several U.S. agencies are being completed this year, including efforts to identify monitoring protocols for MHK and offshore wind projects, and a project evaluating the efficacy of various active acoustic devices for MHK monitoring purposes.

DOE has also initiated several environmental research studies this year that will continue into 2013. DOE's Oak Ridge National Laboratory (ORNL) is working with Alden Laboratory to assess fish injury, morality, and behavior around a hydrokinetic turbine in light and dark conditions in a test flume. ORNL is also assessing the effects of EMF and turbine noise exposure on freshwater fish behavior in a net-pen mesocosm setting. SNL has begun to develop a model to assess the effects of a WEC on the hydrodynamics and sediment transport in a coastal system.

Participation in Collaborative International Projects

Annex IV is an international ocean energy environmental data sharing effort, led by the United States and comprised of six member nations (Canada, Ireland, Spain, Norway, and New Zealand), to expand global knowledge of current research and monitoring efforts on the potential environmental effects of ocean renewable energy development around the world. In 2012, the team working on this effort worked to gather data on environmental research occurring worldwide, to compile that research into a central database, and to draft a final report on the effort. The final report, the database, and its contents were reviewed by an international group of experts at a workshop in Ireland in October. The final report, comprised of three environmental issues presented as case studies, and the metadata from international research studies and device monitoring efforts will be housed on *Tethys* and made publicly available in early 2013. The U.S. is currently proposing an extension of Annex IV to the OES member nations.

Annex V, which began in 2012, is intended to provide a global forum for exchanging and assessing ocean energy project technical data. The annex is comprised of a series of workshops that share knowledge and understanding of data and analysis across the spectrum of ocean resources and energy generation devices. These are expected to include:

- The measurement and analysis of ocean kinetics
- Sensors and instrumentation design and use
- Experimental methods and protocols

- Device design and verification methodologies
- Methods of measuring and assessing effects on the marine environment
- Project data and methods for life cycle cost analysis

Workshop I of Annex V, Open Water Testing, was held in October 2012 in conjunction with the International Conference on Ocean Energy in Dublin, Ireland. Fifteen of the nineteen OES countries are participating in Annex V, and eleven of those countries participated in Workshop I. The Workshop provided data exchange on test facilities currently operating, facilities being planned or under development, and experiences of device developers that have performed open water testing. The resulting report will detail the Workshop discussions including the operational and business challenges of test facilities, the needs of device developers for the testing sites, and planning available test sites so as to allow technology to proceed quickly.

TECHNOLOGY DEMONSTRATION

In 2012 the ocean energy industry in the United States saw several deployments of pre-commercial scale devices. During that time three of these projects received the first ever hydrokinetic licenses from the Federal Energy Regulatory Commission (FERC) for the future build-out of their commercial scale projects. The following section details these deployments and licenses. For additional information on MHK technologies in the U.S. and abroad see DOE's Marine and Hydrokinetic Technology Database http://www.water.energy.gov/hydrokinetic/default.aspx.

On August 13, 2012 FERC granted **Ocean Power Technologies** (OPT) a commercial license for the full build-out of the 1.5 MW, grid-connected Reedsport OPT Wave Park Project (P-12713). This is the first commercial license issued for a wave power project in the U.S. The license provides approval for the deployment of up to ten grid-connected OPT devices for 35 years. OPT is working through the permitting and licensing process to expand this site to 50 MW capacity. This expansion project is called Phase III, and received a Preliminary Permit on March 15, 2011 (P-13666). From 2009 to 2011 OPT tested its 40 kW PowerBuoy in 30 m depth, approximately three-quarters of a mile offshore at the Kaneohe Bay Marine Corps Base on Oahu, becoming the first grid-connected wave energy device in the U.S. OPT's 150 kW WEC device (PB150), initially scheduled to deploy in 2012, was plagued by weather delays and will therefore launch in 2013. This project will collect detailed data during two years of operation. Additionally, OPT plans to test their utility scale 500 kW device (PB500) in early 2013.

On December 22, 2011 the New York State Department of Environmental Conservation granted **Verdant Power** a Water Quality Certification Permit for the Roosevelt Island Tidal Energy (RITE) Project. On January 23, 2012 FERC granted Verdant Power a 10-year Hydrokinetic Pilot Project License (1.05 MW), making it the first licensed tidal power project in the U.S. The project is being developed in a phased approach to include up to 30 turbines providing 1 MW of power. Following the successful testing of Verdant's 4^{th} generation Free Flow Kinetic Hydropower device at the RITE project from 2006-2009, Verdant's 5^{th} generation device is planned for installation at that site as well. On September 7, 2012 Verdant completed an in-water dynamometry test, with over a quarter million valid data points recorded. The dynamometer turbine was removed the following week and transported by barge to Verdant's site in Bayonne, NJ. Data from blade strain gage data recorders in the rotor hub are being processed and analyzed in conjunction with the other dynamometry data to inform ongoing numerical modeling efforts.

On February 27, 2012 **Ocean Renewable Power Company** (ORPC) received an 8-year Pilot Project License from FERC for the 300 kW Cobscook Bay project in Maine, making it the second licensed tidal power project in the U.S. On April 26, 2012 the Maine Public Utilities Commission approved the primary contract terms of power purchase agreements (PPAs) for the ORPC Maine Tidal Energy Project. These will be the first long-term PPAs for tidal energy in the United States. On July 24, 2012 ORPC held the dedication ceremony for the project, making it the first commercial tidal energy project in the U.S. The company's first TidGen™ TGU device was successfully deployed on August 14, 2012 and grid-connected the following month.

Public Utility District No.1 of Snohomish County (SnoPUD) filed a Final License Application with FERC on March 1, 2012 and is awaiting FERC approval for the Admiralty Inlet project (Everett, Washington). The project proposes to deploy, operate, monitor, and evaluate two Open-Centre Turbines, developed and manufactured by **OpenHydro Group Ltd.**, in Admiralty Inlet of Puget Sound.

In 2012 **Northwest Energy Innovations** (NWEI), in partnership with other industry leaders from New Zealand, verified the ocean wavelength functionality of the Wave Energy Technology-New Zealand (WET-NZ) device through wave tank testing and a controlled open sea deployment of their 1:2 scale device. The WET-NZ was deployed on August 22, 2012 at the Northwest National Marine Renewable Energy Center (NNMREC) off the coast of Oregon. Six weeks of successful testing were completed and the device was removed. Following testing and the award of a DOE grant, the WET-NZ device will begin a 1 year test at the U.S. Navy's Wave Energy Test Site (WETS) located at the Marine Corps Base on Kaneohe Bay, Hawaii.

This past year **Resolute Marine Energy** (RME) deployed a surge wave energy converter at Jennette's Pier in Nags Head, North Carolina. The full scale, TRL 5/6 device was deployed for approximately one month in November of 2012. RME is continuing the development of their technology and plans to test the device again in early FY13.

Vortex Hydro performed open water testing of a hydrofoil device in the St. Clair River in Port Huron, Michigan. The device was deployed in September of 2012 for two weeks to test enhancements to the energy capture and efficiency of the device.

In 2012 **FloDesign** completed a short demonstration test of their device with funding from DOE's SBIR/STTR Program. The developer conducted two in-water demonstrations with their Mixer Ejector Hydrokinetic Turbine device (a ducted turbine) at the University of New Hampshire's Tidal Energy Site and in the Muskeget Channel in Massachusetts.

Oscilla Power was selected for a $1 million DOE SBIR Phase II award to further develop its iMEC™ wave energy harvesting technology with testing of a sub-scale system in late 2013 and early 2014 in open water off the coast of New Hampshire. The technology uses reverse magnetostrictive technology to convert mechanical energy into electrical energy without moving parts.

Dehlsen Associates, LLC demonstrated its Centipod wave energy converter off the coast of Santa Barbara, California in late November. This test did not include power generation, but data gathered from the test will inform the design and construction of a larger scale device that will be tested in early 2013.

Testing Infrastructure Development

Test facilities are intended to offer a wide range of testing services that address both technical and nontechnical barriers of MHK systems. By spearheading the development of a testing infrastructure, DOE ensures that many more prototypes from a diverse set of technology developers can be tested than if each developer had to carry the cost of developing, permitting, and installing its own test facility. In this way, superior technology performance and design will determine which technologies will succeed, rather than those able to garner the most funding. In 2012 the United States' testing infrastructure advanced significantly.

Northwest National Marine Renewable Energy Center (NNMREC) – Wave and Tidal Test Facility

NNMREC completed permitting requirements for an open water wave energy test site in Reedsport, Oregon in 2012, and on August 22, scientists from NNMREC demonstrated a new $1.5 million testing device called the Ocean Sentinel. Resembling a bright yellow dock equipped with an array of measuring instruments, the Ocean Sentinel floats on the water's surface and is currently set up in a 1 square-mile test site two miles northwest of Yaquina Head off the Oregon coast. The Ocean Sentinel is designed for testing wave energy converters and provides power analysis, data acquisition, environmental monitoring, and an active converter interface to control power dissipation to an on-boar electrical load.

During 2012, NNMREC received a new DOE award of $4 million to complete the design of a full scale, grid-connected ocean energy test facility at NNMREC capable of accommodating commercial scale devices. The Pacific Marine Energy Center (PMEC) will be the first full scale, grid-connected test center in the U.S. With additional funding from the Oregon Wave Energy Trust, NNMREC will partner with the widely successful European Marine Energy Center (EMEC) to complete the development plan for PMEC.

Southeast National Marine Renewable Energy Center (SNMREC) - Ocean Current Test Facility

SNMREC is working to advance research on open-ocean current systems by building the capability, infrastructure, and strategic partnerships needed to support technology developers on the path to commercialization. During 2012, SNMREC received a new DOE award of $1M to continue infrastructure development. Upon completion of regulatory activities underway, near-term SNMREC plans include installation of a non-grid-connected offshore test berth and deployment of an experimental ocean current-energy conversion research device. The research device will provide a testing platform to evaluate commercial device components and sub-systems.

Hawaii National Marine Renewable Energy Center (HINMREC) – Wave and Ocean Thermal Energy Conversion Test Facility

The primary objective of the Hawaii National Marine Renewable Energy Center (HINMREC) is to facilitate the development and implementation of commercial wave energy systems. In 2012, HINMREC received a new DOE award of $2M to apply their capabilities and experience towards the build-out of the Navy's Wave Energy Test Site (WETS). HINMREC is collaborating with the U.S. Navy to expand existing facilities to provide multiple-berthing for devices in the 100 to 1000 kW range. WETS, housed at Marine Corps Base Hawaii in Kaneohe Bay offers a grid-connected test berth at 30 m depth. The expanded test site will allow for testing in water depths ranging from 30 m to 70 m. The vision for HINMREC consists of participating in activities at a fully operational WETS and continuing to provide services required to evaluate WEC designs.

BELGIUM

Mathias Damen and Julien de Rouck
Ghent University

INTRODUCTION

Even with a small coastline and sea territory, the developments in Belgium prove to be interesting. A first research device is about to be deployed, first targets are set for the construction of a wave energy park in the Belgian part of the North Sea and a Belgian company is involved in the project development of a first big scale tidal energy parks.

OCEAN ENERGY POLICY

Strategy and National Targets

Belgium has to increase its share on renewable in the gross final energy consumption to 13% by 2020. According to Eurostat, this share has been increasing steadily up to 6.8% in 2010. The burden sharing between the Federal and regional states is still a point of discussion. On the Federal level, a strong increase is observed in 2011/2012 and will continue in the next years, mainly due to the developments of offshore wind (target set at 2 GW, currently 379.5 MW installed offshore). No specific targets have yet been set for wave or tidal current energy.

Support Initiatives and Market Stimulation Incentives

Belgium has implemented the system of Tradable Green Certificates (TGC) to support energy production from renewables. The Regional Government of Flanders has approved a TGC for wave and tidal current energy of €90/MWh, guaranteed for 10 years, but it is to date unclear if this TGC could be applied since the sea area from the low water mark is under Federal, and not regional, jurisdiction. On the other hand, the Federal Government has approved a TGC for 'hydroenergy' for €50/MWh (10 years) but to date it is unclear if 'hydroenergy' also encompasses wave or tidal current energy, since hydroenergy is not defined as such in the Federal law. If wave and tidal current energy were excluded from 'hydroenergy', support would have to fall back on the lowest TGC available, which is €20/MWh. Hence, there is significant uncertainty about the exact level of support. The Federal Department of Economy started up an evaluation in conjunction with the stakeholders to adapt this support system and to provide clarity and certainty about the exact support tariff. Meanwhile, the Flemish Government is thinking of an appropriate way of supporting ocean energy in the Belgian part of the North Sea.

Main Public Funding Mechanisms

The Flemish Agency for Innovation by Science and Technology (www.iwt.be) has co-funded the FlanSea project for €2.4 million (with €1.3 million funded by the private partners) over a period of time of 3 years.

Relevant Legislation and Regulation

The Belgian maritime spatial plan foresees an area for the 'exploitation for offshore wind, wave and tidal energy'. This area has been divided into 7 zones for which the Government gave concessions for alternative energy project development. The last concession was granted in July to the temporary trading company Mermaid, which plans on installing a combined wind and wave energy park. These plans will lead to more clarity on the TGC details for ocean energy in the coming years.

The governmental agreement of the 7 December 2011 expresses the intention to determine a new area in the Belgian part of the North Sea for offshore energy development, which can raise interesting opportunities for the development of wave and tidal energy in Belgium.

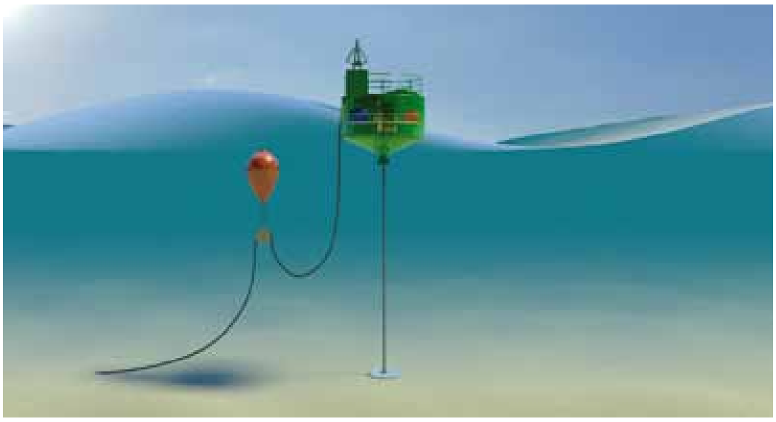
Relevant Documents Released

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

RESEARCH & DEVELOPMENT

Government Funded R&D

The FlanSea project, which aims at designing and developing a wave energy converter for the low wave energy in the Belgian part of the North Sea and the moderate wave climates further in the North Sea, will reach the deployment phase in 2013. The project partners are DEME Blue Energy, Cloostermans, Harbour of Ostend, Electrawinds, Spiromatic, Contec and 4 research groups from Ghent University.



FlanSea (Flanders Electricity From the Sea) point absorber technology
www.flansea.eu

Laminaria has developed a multidirectional surge device for which they got some support from the IWT (Flemish Agency for Innovation by Science and Technology). Tank testing has been performed and they are patent holders.

Participation in Collaborative International Projects

Ghent University participates in the WECWakes project, funded by Hydralab in order to assess wave energy converter farm interactions in a physical wave flume (€225 thousands).

TECHNOLOGY DEMONSTRATION

New Developments

Mermaid has received the concession for their plans to build a combined wind and wave energy park in the 7th and most northern part of the Domain Concession Zone. The idea is to use synergies of offshore wind and wave energy as a way of overcoming certain obstacles for implementing a wave energy park. A total amount of 20MW of wave energy is projected along with the 450MW of wind energy. The wind energy is to be installed by 2017. The wave Mermaid is a partnership that consists of 65% of OTARY RS and 35% of Electrabel (GDF SUEZ). OTARY is a collaboration of Aspiravi, DEME, Electrawinds, Nuhma, Power@Sea, Rent-A-Port, Socofe and SRIW Environment.

Another interesting development is that the Belgian company DBE (Deme Blue Energy) together with DP Marine Energy has an agreement for lease from the Crown Estate for a 100MW tidal project off the northwest coast of Antrim at Fair Head in Northern Ireland and for a 30MW tidal project 8km off the tip of the Rhinns of Islay in Scotland.

GERMANY

Jochen Bard
Fraunhofer IWES

OCEAN ENERGY POLICY

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

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

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

In August 2012 the German government adopted the draft for the Third Act Revising the Legislation Governing the Energy Sector. The new legislation aims to speed up the expansion of offshore wind farms. The major focus is on a system change towards a consistent and efficient offshore grid expansion by introducing a binding offshore grid development plan. This will improve coordination of grid connections and offshore wind farms. In addition, a compensation regulation for the construction and operation of grid connections to offshore wind farms will be introduced.

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

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

RESEARCH AND DEVELOPMENT

In the public sector, around 15 R&D institutes and universities are involved into developing wave, tidal current and osmotic power mainly in the framework of European research projects. The National funding in the framework of the national energy research programme for renewable energies was approximately €160 million in 2011. This programme is open to ocean energy research. Up to now, six technology projects related to the development of components and concepts for tidal turbines and wave energy components have been funded by the federal Environment Ministry (BMU) with a total amount of around €7 million.

The first two projects operating from 2001 to 2008 were related to the development of a tidal turbine concept and components. Fraunhofer IWES (former ISET) and LTI Power Systems developed a pitch system, the dynamic simulation, control engineering and new drive train concepts for marine current turbines, such as the British Seagen concept, which was successfully installed in 2008. Siemens acquired the complete shareholding of MCT in 2012, which is now operated as a Siemens business under the Siemens Solar & Hydro Division. With this, tidal turbines have become a part of the Siemens energy technology portfolio. There are great expectation about the realisation of the first two farm projects namely, the 8-MW-project Kyle Rhea in Scotland and the 10-MW farm at the Anglesey Skerries in Wales. These sites have been leased by The Crown Estate.

From 2008 to 2011 another public funded project was executed by Voith Hydro Ocean Technologies GmbH & Co. KG in cooperation with Loher GmbH for the development of a tidal turbine concept. It is based on a fully submerged horizontal turbine equipped with a variable speed direct drive permanent magnet generator and symmetrically shaped fixed blades which allow the operation in two opposite flow directions. A first 110 kW pilot installation has been installed within 2011 at a site off the coast of South Korea near the island of Jindo. This test facility was built as a 1:3 scale model and is used primarily to demonstrate the new technology developments under real operating conditions. The turbine has a rotor diameter of 5.3 m, and achieves a rated capacity of 110 kW with a current speed of 2.9 m/s. The test power plant fully met the expectations of Voith's engineers. The calculated power curves have been confirmed. In addition, the system is able to keep the turbine running at the optimum power generation point at all times, even in the exceptionally turbulent currents that occur at this location.

The Jindo power plant stands on a gravity base foundation due solely to its intrinsic weight. For recovery during maintenance, a special recovery module on a drive chain slides down to the turbine nacelle, grasps it from below and then lifts it out of the gravity structure. The nacelle is then lifted by winding up the guide chains to the water surface.

A second device with 1 MW capacity is planned to be installed at the European Marine Energy Centre (EMEC) for testing with funding from the UK Marine Renewables Proving Fund (MRPF). The construction and installation of the full-size machine was the consequent continuation of Voith's test program. It allows the low-maintenance current turbine systems to be developed in a commercial size. With the exception of a number of small modifications, the EMEC turbine is basically an up-scaled version of the system in Jindo. The simplicity and sturdiness of the optimized system has been consistently maintained. The turbine reaches its rated capacity of 1 MW at a current speed of 2.9 m/s. It has a rotor diameter of 16 m. Unlike the Jindo turbine, the test system is mounted on to a monopile drilled into the seabed. The turbine rests under its own weight on the support structure and is installed and removed with the help of crane ships.

Voith Hydro Ocean Current Technologies, Heidenheim, is a Center of Competence for the development of ocean current power stations. Voith Hydro Ocean Current Technologies is an 80:20 joint venture with the RWE Innogy Venture Capital Fund I.

Voith Hydro Wavegen in Inverness, Scotland is a "Center of Competence" in wave power, driving forward research and development in wave power systems. Voith Hydro Wavegen focuses on the conversion of wave energy using the principle of the oscillating water column (OWC). In the year 2000, the 250 kW trial system Limpet was brought into service on Islay at the Scottish west coast, where it has been generating electricity and feeding it into the network ever since. Limpet is the only wave-powered plant worldwide to have continually produced power over the past 10 years, feeding it into the network on the Isle of Islay. Up until the end of 2011, it had been running for more than 75 000 operating hours. System availability stands at over 98 %, and has been so continuously since 2009.

The world's first breakwater wave power plant was commissioned in the summer of 2011 on the Spanish Atlantic coast at Mutriku using Voith Hydro Wavegen technology. It has a nominal output of some 300 kW, and can supply around 250 households. The system consists of 16 Wells turbines, each with a rated performance of 18.5 kW. It was built into the breakwater around the harbor at Mutriku, which was re-built by the local municipality. The Mutriku power plant has been operated successfully since its opening by the Basque energy agency, EVE, and is currently the only commercially-operated wave power station in the world. (source: Voith Hydro)

In 2011 the chair of structural analysis at the Technical University Munich started a collaboration project with Ed. Züblin AG on the numerical simulation and optimisation of the foundations of ocean current turbines with a focus on the fluid structure interaction. The public funded project will be completed in 2013.

The Institute for Fluid and Thermodynamics (IFT) of the mechanical engineering department at the University of Siegen started a 3 year public funded research project on the development of a bidirectional radial air turbine for application in OWCs at the end of 2011. Based on analytical, numerical and experimental methods using a specially designed air turbine test facility a radial turbine design is developed and optimised. The university collaborates with Voith Hydro on the design optimisation of Wells turbines. The Limpet site can be used for field tests of the new design.

Since 2012 Andritz Hydro GmbH develops drive train concepts for tidal turbines with around €1 million funding from the BMU. The focus of the project is the economic and technical optimisation of a variable pitch mechanism for bidirectional operation and the blade connection to the hub. The design will aim at full scale rotors with maintenance intervals of 5 years. Under the Andritz Group based in Austria Andritz Hydro Hammerfest established in 1997 in Norway represents the technology provider in the tidal power business. Based on a 300 kW tidal turbine, tested in Norwegian waters, a 1 MW tidal device was developed and tested at EMEC site before becoming part one of the world's first tidal arrays, planned for installation in Scottish waters in 2013. (source: Andritz Hydro)

The German marine propulsion specialist Schottel placed an investment into the UK tidal-power technology developer TidalStream Ltd. in 2011. For Schottel renewable energy is an interesting and forward-looking addition to the traditional product range portfolio. The Triton platform technology comprised of a semi-submerged turbine-carrying catamaran structure is expected to enable efficient installation of large power arrays and provides easy maintenance access. The Triton S concept is tailored to operate totally submerged for "non-surface piercing" applications by using a rigid swing-arm tether foundation, designed to be towed to site, mated with turbines and deployed into operating position via water-ballasting. After completing the ongoing 1:10 scale field test, upscaling of the technology is ongoing with the Triton 3 for intermediate water depths with the capacity to generate up to 3MW from a single installation followed by the Triton 6 designed for deep water sites to accommodate turbines of up to 10MW capacity.

At the occasion of the International Tidal Energy Summit in November 2012 in London, Schottel presented its first TIDAL Generator STG 50. The light-weight and robust tidal generator is based on the fact that reducing turbine size leads to a better ratio of power and material use. High overall power can be reached with a higher number of turbines. STG 50 is a horizontal free flow turbine with a rotor diameter of 4.0 to 4.5 m and a rated power of 45 to 50 kW. It is designed to be composed in arrays of various types and sizes depending on the available space and the output expectations. The turbine is equipped with speed increaser and an asynchronous generator. Each of the turbines is connected to a frequency converter feeding into a common DC bus installed on the tidal platform. Finally a common frequency converter together with a large transformer is used to produce grid-ready electricity. Due to the modular approach, the turbine can be implemented in rivers, sea straits and offshore in jetty or floating platforms as they are developed by TidalStream.

The turbine design has been supported by various model tests and RANS-CFD simulations. The drive train was subjected to extensive laboratory tests. Two complete STG drive trains were installed in a submerged back-to-back configuration. Full-scale tests have been performed with the entire converter including the rotor. For this purpose, the unit was fixed to a tug (see photo). This setup allowed for the adjustment of various flow conditions. Different sets of rotor blades as well as the entire power generation chain have been tested. (source: Schottel Group)

Schottel stg50 prototype

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

A national Master Plan Maritime Technologies has being prepared under the coordination of the Ministry of Economics and Technology to support the development of the maritime technology industry in the coming years. The goal is to develop recommendations for a future coordinated maritime technology policy, at federal and state level, and the clustering of the core competencies of industry and science through enhanced networking and clustering. It is anticipated that ocean energy technologies will play a role in the plan.

TECHNOLOGY DEMONSTRATION

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

NORWAY

Carl Gustaf Rye-Florentz
NORWEA

INTRODUCTION

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 Norway. The academic R&D activity also remains strong in all aspects of ocean energy. The governmental support and encouragement for R&D is good, especially for research. Several prototypes and demonstration units have received public support over the last years, but it is difficult for developers to achieve private funding.
Norway joined a green certificate market with Sweden on 1January 2012. One certificate per MWh delivered is given to all new renewable energy generators for 15 years. No extra certificates are given for ocean energy generation and hydro, wind and bio power are the only realistic producers that reach grid parity.

OCEAN ENERGY POLICY

Strategy and National Targets

Norway has no special policy for ocean energy, but ocean energy is included in more general renewable energy policies and programmes. An updated governmental strategy for ocean energy is expected in 2013.

Support Initiatives and Market Stimulation Incentives

In 2011, Norway and Sweden signed an agreement for a joint green certificate market. From 2012, one certificate per MWh will be given to all new renewable energy generation in 15 years, independent of technology.
The price per certificate is driven by the market with a common target of 26.4 TWh by the end of 2020. The total compensation (el-spot + certificate) for the renewable producers are in the long term believed to be approximately €70-80 /MWh.
A total income of €70-80/MWh is almost certainly not enough for wave and tidal projects in the next decade. Instead, the governmental support programmes for research and development are intended to drive the development.
The Norwegian petroleum tax system offshore has an income tax of 78%, but has special benefits for energy production when used to oil and gas production. Ocean energy plants could benefit from the favourable depreciation rules. The possibility of including offshore wind farms is currently being discussed.

Main Public Funding Mechanisms

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

In 2010, Innovation Norway launched a programme supporting prototypes within "environmental friendly technology". Ocean energy is included in this definition. Projects are supported with up to 45% of eligible costs.
The Research Council of Norway has an energy research programme called ENERGIX. This programme supports R&D within all renewable energy technologies.
For 2012, these three institutions had a combined budget of approximately €110 million.

Relevant Legislation and Regulation

The Ocean Energy Bill, which regulates renewable offshore energy production, entered into force on 1 July 2010. According to this new legislation licenses to build offshore wind, wave and tidal farms in certain far-shore geographical areas cannot be given without a prior governmental process, in which suitable areas are identified. This legal framework is very much inspired by similar legislation in the Norwegian petroleum sector.

As a follow up on the Ocean Energy Bill, a group of relevant governmental bodies has identified 15 areas that could be suitable for large-scale offshore wind power. More detailed "strategic consequence assessments" will be finalized late 2012.
Meanwhile, the licensing body NVE has continued to prioritize small scale demonstration projects located near shore according to the existing Energy Bill. The licensing process is efficient and pragmatic since the demonstration projects are small in physical installations and operation time.

RESEARCH & DEVELOPMENT

In Norway, ocean energy is included in more general renewable energy support programmes. The overall funding for renewable energy R&D made available through the Norwegian Research Council, Innovation Norway and ENOVA has increased significantly over the last years. This has also resulted in increased funding for ocean energy projects as well, from research to prototypes and demonstration.

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

Runde Environmental Centre (REC) is located on the island Runde, off the Norwegian west coast. REC is a research station with activities within marine biology, oceanography and ocean energy.
REC has developed leading in-house competence on environmental monitoring, and offers ROV survey, field sampling and laboratory facilities to investigate environmental impacts of the tested devices.

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

TECHNOLOGY DEMONSTRATION

Operational Ocean Energy Projects

Andritz Hydro Hammerfest
The company was founded in Norway in 1997 by the local utility company Hammerfest Energy and is currently owned by Andritz Hydro, Iberdrola and Hammerfest Energi. Andritz Hydro Hammerfest is among the leading tidal energy technology developers in the world and is now taking the step into commercial delivery. The Company has unrivalled commercial operation experience and has received Carbon Trust funding for the tidal turbine development.

Fred Olsen
The company Fred. Olsen has continued to test their wave energy buoy "BOLT" in Norwegian waters. 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, but has produced many MWh of electricity to an onboard load bank. Sea trials will continue in 2013.

In a direct continuation of the work with "BOLT", Fred. Olsen was awarded grant support from the UK Technology Strategy Board. This, in turn, led to the design, manufacturing and deployment of a full-scale device at the "FABTest" test site off Falmouth in South West England. The unit, which has three power take

-off units with a total of 240 kW installed capacity, was named "Lifesaver" and deployed in March 2012. Sea trials with electricity production will continue for a full year before the unit is deployed elsewhere.

Statkraft's Osmotic Power Prototype

The principle of osmotic power is utilizing the entropy of mixing water with different salt gradients. An osmotic power plant extracts power from salinity gradients by guiding water with low salt gradient and water with higher salt concentration into separate chambers, divided by a membrane. The salt molecules pull the water with low salt gradient through the membrane due to osmotic forces, creating a pressure on the side with higher salt concentration that can drive a turbine.

Statkraft opened the world's first osmotic power plant in 2009 in Norway. The operation of the plant proves that power from salinity gradients can supply a stable base load of renewable energy, with a minimal ecological footprint. The next big milestone is the decision to build a 2 MW pilot plant. Investment decision is planned for 2013. Furthermore, the goal is to build a full-scale demonstration plant within 2020.

New Developments

STRAUM

STRAUM is a Norwegian technology developer and supplier of wave, tidal and offshore wind power systems. STRAUM's business idea is to develop, design and deliver a unique range of marine renewable power plants together with strategic partners. The STRAUM technologies are all "in-front" and backed by strong IP portfolios, and include the following power plant systems: Hydra Tidal™- tidal & ocean current power plants, OWC Power™- wave power plant and WindSea Floater™/WindSea Jacket™ - floating and fixed offshore wind power plants.

The Hydra Tidal™ floating ocean energy system is one of a very few full-scale tidal energy plants built and deployed in the world. STRAUM is planning to re-deploy the Morild II tidal prototype that at the moment is at a shipyard for repair and maintenance. The business idea of oscillating water column (OWC) power is to develop and commercialize a wave power concept based on the OWC principle . For this technology, STRAUM is currently performing a small scale testing programme both for the wave chamber and the air turbine. WindSea FloaterTM is a new concept for offshore wind turbine platforms, which consists of a floating platform supporting three windmills. STRAUM is looking for project financing for a large scale prototype test to be able to verify the results from small scale testing. The WindSea JacketTM concept distinguishes itself by cost effective fabrication, transport and installation. The technology is based on a low weight modularized jacket. Currently STRAUM is talking to end users and EPC contractors to qualify the technology for commercial offshore wind projects.

STRAUM is owned by Ard, a privately owned and independent industrial investment company with long traditions in Norwegian industrial development, oil & gas and hydro power. Through its owner STRAUM has strong ties and alliances to renowned technology provider such as NLI and Rainpower, leading suppliers to the oil & gas and hydro power markets respectively. In 2012, STRAUM has been chosen by the Global Cleantech Cluster Association (GCCA) as a Later Stage Award Top 30 finalist for their in front tidal and hydro power technologies. For further information on STRAUM, please visit www.straumgroup.com

Havkraft AS

Havkraft is a Norwegian technology company specialized in onshore, nearshore and offshore installations for the utilization of wave energy for wave damping and power production, with both low-tech and high-tech solutions for all markets. The company shareholders are founder and inventor Geir Arne Solheim and Fjord Invest. Havkraft cooperates amongst others with Dr. Ing. Karl Christian Strømsem. Tests conducted in 2012 show that the H-WEC (Havkraft Wave Energy Converter) is a perfect wave energy converter, with the potential to capture the complete energy field and to utilize all the natural frequencies in the waves. This high efficiency combined with a simple construction - with no movable parts in contact with sea - is an improved and patented OWC device with low OPEX and CAPEX. A large scale test programme has started in 2012 with support from Innovation Norway and co-investors.

Langlee Wave Power 2012

The technology that Langlee offers is based on the valuable experience of offshore petroleum engineering in Norway. As a result of marine renewable energy research since the inception of the company in 2006, Langlee has developed a wave energy converter that will produce electricity at a lower cost with respect to existing technologies, without compromising the quality, efficiency and with no visual impact.

Langlee Wave Power has decided to devote all its efforts in a unique area, and boost afterwards growth to a global market. With this idea in mind, Langlee has established a Spanish subsidiary in Gran Canaria, in the field of the ZEC (Canary Islands Special Zone), with the most attractive tax incentive and best wave power conditions in Europe. The first prototype converter wave power rated at 100 kW could produce around 300 MWh of clean energy per year on the Canaries, corresponding to about 300 households.

Langlee Wave Power and Zamakona shipyards have recently signed an agreement for the local production of the metal structure. Zamakona, which is one of the most important shipyards and repair groups in Spain, along with Langlee Wave Power, will work together in a consortium to develop its activities in the framework of the EEA Grants. Langlee is receiving subsidies funding from Innovation Norway.

Intentium

The Norwegian company Intentium AS has been developing an offshore floating wave energy converter since 2007. With a wider stabilized float, energy from a larger width of the wave front is harvested. The concept emphasizes robust solutions by using a PTO with hydro-power similarities, disconnected from the moorings. In 2012, the concept has gone through extensive ocean basin testing at Aalborg University, through the EU funded initiative MARINET. Results, backed up by previous numerical simulations conducted by SINTEF MARINTEK, show a persistent efficiency through a diversity of wave conditions. Present status indicates a first large-scale prototype in the order of 200kW.

Flumill

The company Flumill has obtained a licence from NVE for deploying up to 5 MW tidal energy production in Rystraumen in Troms in the northern part of Norway. A grid connection arrangement has been entered into with Troms Kraft.

Flumill is planning to build and install a full-scale grid connected demonstration system in Rystraumen in 2013. Enova has granted support of NOK 57,3 million to the project. The demonstration system will have a rated capacity of about 2 MW.

Deep River

Deep River has developed a tidal, current and river plant. The company plans to install a demonstration system in a Norwegian tidal stream in 2013.

Tidal Sails

Tidal Sails is developing and constructing energy plants generating electricity from ocean currents and tidal streams. Aluminum sail profiles attached to wires sail with the current at an angle, capturing energy and converting it into clean electricity. Linearly moving sails have great extraction efficiency, thus dramatically reducing the cost of the electricity generation. Tidal Sails technology may be used in different settings and is protected by several patents worldwide.

Tidal Sails has a small scale demonstrator operating in a stream outside Haugesund, Norway. This has a nominal capacity of 28 KW, and provides an excellent basis for scaling up systems to the range of several MW. The hydrodynamic forces work exactly the same in any scale.

In 2012, the company has delivered an application for a demonstration project of 3MW at Kvalsundet near Hammerfest, in Norway. Yearly production is estimated to be 8 GWh.

Ocean Energy

Ocean Energy AS has designed a wordwide patented wave energy plant. The technology is based on the Swedish wave company Seabased AB, but Ocean Energy has developed and patented a “Storm Buoy”. The Storm Buoy can be submerged and withstand extreme waves. The solution is developed in cooperation with the leading environments at universities in Norway (NTNU) as well as the “Maritime Cluster” at Ulsteinvik, Sunnmøre in western Norway.

The project is supported by Innovation Norway and Ocean Energy plans a demonstration at Runde in 2013.

MEXICO

Sergio M. Alcocer[1], Gerardo Hiriart[2] and Rosalba Cruz[1]
[1]Universidad Nacional Autonoma de Mexico
[2]Energias Alternas Estudios y Proyectos SA de CV

INTRODUCTION

In recent years, Mexico has implemented major changes in the energy sector, favouring renewable energies. These changes resulted from the integration of a new legal framework towards energy transition and the production and use of cleaner energy.
The country has significant potential for ocean energy due to the large coastline, primarily in the Upper Gulf of California: however, in Mexico fossil fuels are still the most important sources for power generation.
Several documents denote that the use of clean technologies should increase and targeted reaching a production of 35% of power generation from clean energy, as in the case of the National Energy Strategy, the Electricity Sector Outlook and the Renewable Energy Outlook.
Moreover, there are several programmes that encourage the use of renewable energies, through funding for research projects that promote the development, use and application of clean technologies, an example is the Fund for Energy Sustainability, the Fund for Energy Transition and the Sustainable Use of Energy and the different funds for Energy Efficiency and Renewable Energy of international type.
Mexico does not have a specific policy for ocean energy generation, but there are various mechanisms for the regulation of energy that determine the type of renewable sources that are suitable for power generation, such as ocean energy. The Law on the Use of Renewable Energy and Energy Transition Financing refers to the use of ocean energy in its different ways to generate energy. For its part, the National Water Act refers to the use of national waters for various uses including power generation.
Currently and although Mexico has no pilot or commercial ocean energy generation projects, some studies and pilot projects are being conducted by the Federal Commission of Energy (CFE), the National University of Mexico (UNAM) and other institutions to demonstrate the feasibility for harnessing ocean energy, as in the Upper Gulf of California where is estimated a potential production of 23,000 GWh/year and 26GW installed.
Finally, the formation of a group of specialists from different academic institutions, government agencies and private companies focused on ocean energy is in the process, for exploitation, uses and applications.

OCEAN ENERGY POLICY

The renewable energy policy in Mexico (including ocean energy), is based on the Law of Public Electricity Service (LSPEE), which together with the Energy Regulatory Commission (CRE), indicate the rules for generating, conduct, transform, distribute and supply energy.

There are other laws relevant to the determination of the energy policy, such as the Law on the Use of Renewable Energy and Energy Transition Financing (LAERFTE) which defines renewable energy sources, applicable for processing permission with the CRE and the Federal Administrative Procedure Act (FAPA) provides special rules of procedure with some general provisions, such as time limits, sanctions, and verification visits appeal.

For the process of implementation of energy policy, and in particular the ocean energy, are considered the Secretary of Energy (SENER), the Federal Electricity Commission (CFE), the Navy Secretariat (SEMARNAT), the Secretary of communications and Transport (SCT) and the Ministry of Environment (SEMARTAT), among others.

Strategy and National Targets

	PERIOD	GOALS
National Energy Strategy	2012-2026	Diversify energy sources, giving priority to increasing the participation of non-fossil technologies and reduce the environmental impact of the energy sector. The goal is to increase the participation of the non-fossil sources in the generation of electricity up to 35% (9.2 % Hydraulic) in year 2026.
Energy Sectorial Program	2007-2012	Participation of renewable energy (including hydro) in the energy matrix increase from 23 to 26%
Special Programme for the Development of Renewable Energy	2009-2012	Installed capacity of 7.6% and power generation between 4.5 y 6.6% from the total national generation from renewable sources (not considering large hydro)
Prospective electricity sector	2012-2026	Develop renewable energy sources to achieve a 25% in generation capacity. This definition includes both large and small hydroelectric. Achieving the goal of 65% based fuels fossils from 2024 to 2026 and keeps this percentage.
Prospective renewable energies	2012-2026	Mexico currently has not pilot or commercial developments generating plants operated by the various forms of ocean energy. Studies by the CFE indicate that there are areas with high potential for exploitation in the country, mainly from tidal power in the region Upper Gulf of California. It is believed that in the reservoir area of 2590 km2, could have a maximum installed capacity of 26 GW, with a production of 23,000 GWh / year.

Support Initiatives and Market Stimulation Incentives

Within the set of policy instruments available in Mexico for the promotion of renewable energy, there is accelerated depreciation for investments in renewable energy, established in 2005, which allows 100% depreciation of investments "for machinery and equipment for the generation of energy from renewable sources. Tariff "0" is exempt from payment of general import tax or export: Machinery, equipment, tools, materials, animals, plants and other items for research or technological developments.

The Rural Electrification Project Renewable Energy Sources promote rural electrification projects within the next five years to 50,000 households in the poorest municipalities in the country with over 60% of indigenous population.

Main Public Funding Mechanisms

Fondo Sectorial de Energía-Sustentabilidad Energética. With the Energy Sector Fund-Energy Sustainability, the Energy Secretariat (SENER) and the National Council for Science and Technology (CONACYT), aims to "promote scientific research and applied technology, and the adoption, innovation, assimilation and technological development in the field of renewable energy, energy efficiency, clean technologies, and diversification of primary energy sources. "The resources for the fund will come from a fee equivalent to 0.13% of the value of crude oil and natural gas extracted by PEMEX.

Fund for Energy Transition and the Sustainable Use of Energy. The Financing Program for Renewable Energy Projects, was created to foster the domestic energy sector through projects, programs and actions to achieve greater use and development of renewable energy sources and clean technologies. The fund's resource is used to promote the energy transition, the energy saving, clean technologies and the use of renewable energy.

Financing Program for renewable energy projects and energy efficiency of International-type. This program is supported by the German Ministry of Economic Cooperation and Development and the Credit Bank for Reconstruction and Development. The goal is to fund environmental measures in SMEs linked to industry and service sectors, to allow a reduction in the negative impact to the environment, and promote efficient use of natural resources. This support includes advice and support of SMEs for investment planning and the preparation of documentation for the loan application.

RESEARCH & DEVELOPMENT

Government Funded R&D

PROJECT	DESCRIPTION	INVESTMENT (USA dollars)
Hydrogenerator QK	The National University of Mexico (UNAM) through its IMPULSA Project (Multidisciplinary Research of University Projects for Leadership and Academic Progress) is improving a private design of a floating hydrogenerator named (QK).	370,000 (Second phase)
SIBEO	The National University (UNAM) through the Institute of Marine Sciences and Limnology is conducting this project. The project consists of a pumping system activated by the resonance of the waves.	370,000
Oceanographic review off the coast of Mexico	The National University (UNAM) through the Institute of Marine Sciences and Limnology presented a proposal to develop an Oceanographic review of the coasts of Mexico to assess the potential of the thermal gradient in some regions in order to use it into air condition systems in hotels.	148,000
Network of Observations and Predictions of ocean variables (ROPVO) on the coasts and ports of the Gulf of Mexico	Since 2005 the National Polytechnic Institute (IPN) trough the Research Centre for Applied Science and Advanced Technology (CICATA) operates four oceanographic stations capable of detecting and monitoring changes in the sea level. The objective of the project is to establish a monitoring system that can led to a prediction method and an assessment of energy potential across the coast and ports of the Southeast of the Gulf.	370,000
Information Recovery and Analysis of wave behaviour	In this project data analysis of wave behaviour is made with information from several sources (remote and in situ sensors, numerical simulations). Numerical models are also used to simulate and predict the directional wave spectrum.	370,000
Wave Energy Potential Assessment in the Baja California Peninsula	This project uses numerical models to simulate waves in different geographical scales with several resolutions in the west coast of Baja California in order to assess the potential of power production in the Peninsula.	148,000
Feasibility analysis of a wave energy power plant in Baja California Sur (BCS)	CFE is trying to identify suitable sites to develop wave energy projects in the future. In Cabo Falso, BCS studies such as maritime climate and bathymetry have been conducted.	74,000
Wave Energy in the Gulf of California	CFE has been developing oceanographic studies, mathematical modelling, geophysics, tectonics and soil mechanics near the Montague Island and Adair Bay to assess the feasibility of a pilot wave energy power plant in the Gulf of California.	74,000
Forecasting System	The project includes the development of a numerical forecasting system of waves and tides under normal conditions, storms and heavy seas in Mexico.	148,000
Atmospheric characterization	The project consists of the characterization of the atmospheric boundary layer in the coastal zone of the Yucatan Peninsula to assess the offshore wind potential.	74,000
Oceanographic buoy	Development of a multisensory oceanographic buoy network to measure several marine and climate variables in order to have a data base and a possible potential assessment.	74,000
Blow Jet	The BLOW-JET is a closed conduit in which, when fully confined, the waves are converted into a flow which increases its velocity inside the device. The end result is an intermittent stream output with significantly faster than it entered the device.	74,000

PROJECT	DESCRIPTION	INVESTMENT (USA dollars)
Optimization of a wave energy utilization	Optimization of a wave energy utilization in narrowing channels and their uptake for hydrogen production. The work is addressed in three main areas.	ND
Building a scale model of an OTEC plant	The aim of this project is to develop a laboratory scale model of a OTEC plant in order to engage students in understanding this process.	ND
Getting Through Osmosis Ocean Energy	Prototypes were developed in the laboratory experiment with different types of membranes and devices.	ND
Turbine IMPULSA	The scope of this project is to design and build a scale model of a prototype.	547,037

Participation in Collaborative International Projects

The National University (UNAM) is participating in the European funded project HESEUS (Innovative technologies for safer European coasts in a changing climate). It is the largest Integrated Project within coastal risk assessment and mitigation funded by the EC and consists of 31 partner institutes from different countries.

The scope of the work is to verify whether there are any possibilities of combining wave energy conversion with coastal protection. The impacts of the project will be focused on reducing technical and non-technical risk in the marine environment as well as reducing the cost per kWh of generated energy, through multipurpose structures designed not only for electricity generation but also for coastal protection. The total investment is 10 million USA dollars.

SPAIN

José Luis Villate
TECNALIA
This report has been prepared with the collaboration of APPA-Marina, the ocean energy section of the Spanish Renewable Energy Association. APPA-Marina represents the voice of the Spanish ocean energy industry with two main objectives: to promote an appropriate legal framework and to facilitate a successful technology development, both with the final goal of putting ocean energy as a relevant contributor to the renewable energy production in Spain by 2020.

INTRODUCTION

The Spanish Renewable Energy Plan 2011-2020, approved in November 2011, includes targets for ocean energy (100 MW of installed power by 2020). However, these targets seem now difficult to achieve since the Spanish Government suspended feed-in tariff support to all the new renewable energy installations from January 2012.

Despite the temporary situation regarding feed-in tariff support, the Spanish ocean energy industry is progressing with several projects in different stages of development. The most advanced one is the Mutriku OWC plant, which has fulfilled one year of operation with the production of 200MWh. Furthermore, two open sea test facilities, bimep and PLOCAN, are progressing and both of them are expected to be in operation in 2013.

OCEAN ENERGY POLICY

Strategy and National Targets

The current ocean energy policy in Spain was approved in November 2011 with the inclusion of ocean energy for the first time in the "Renewable Energy Plan 2011-2020". This plan includes the following targets:

- The first 10MW of installed ocean power are expected by 2016.
- An annual growth rate of 20-25MW between 2016 and 2020 is expected to accumulate to 100MW by 2020.

The plan foresees an important growth of ocean energy after 2020 with the following phases:

1. Reliability confirmation (2010-2015): simulation, modelling and prototypes will be key aspects. Cost of the electricity is not a major issue during this phase.
2. Technology development (2016-2020): demonstration of full-scale prototypes with generation costs between €21 and €33 per MWh.
3. Technology consolidation (2021-2030): commercial deployment of ocean power plants with a cost reduction of the electricity down to €7-€15 per MWh.

Spain is part, together with Portugal, France, Ireland and UK, of the Atlantic Forum, which together with the Directorate General for Maritime Affairs and Fisheries (DG MARE) of the European Commission is developing an action plan for the Atlantic Ocean region. This action plan will have possible projects for funding to support the blue economy and develop innovative ideas to face common challenges. Marine renewable energy will be one of the key sectors to be considered in this Atlantic Strategy. In this context, Bilbao hosted one of the workshops to contribute to the action plan and OES was represented with the participation of the Spanish alternate as the moderator of a session on marine renewable session.

One Spanish region has defined specific strategies and targets for ocean energy: the Basque Government approved in December 2011 its Energy Strategy for 2020 which includes a specific initiative to speed up technology and commercial development of weave energy and sets a target of 60MW by 2020.

Support Initiatives and Market Stimulation Incentives

The Spanish Renewable Energy Plan 2011-2020 includes some strategic actions to facilitate the achievement of its targets. Regarding ocean energy, the following actions are proposed:

Technology strategy actions:

- An intensive R&D programme focused on new designs and components clearly aimed at reducing costs and improving the survivability of the devices.
- A demonstration programme aimed at developing and testing small scales prototypes.
- Support of experimental testing infrastructures to validate the performance of the devices during the full life cycle. This includes a specific and simplified consenting process for experimental platforms.
- Collaboration with other European countries by means of an initiative of the European Union focused on improving the reliability and new installation techniques.

Non-technology strategy actions:

- Definition of a specific regulatory framework for ocean energy projects, with simplified licensing processes.
- Modification of the feed-in tariff system to create a different group for ocean energy more appropriate for its stage of development.
- Planning of grid infrastructures to facilitate ocean energy integration.
- General dissemination and promotion campaigns amongst different stakeholders to improve social acceptance and to facilitate a new market.

Main Public Funding Mechanisms

The first Royal Decree of the Spanish Government in 2012 has meant a serious step back for ocean energy development with the suspension of the support through feed-in tariffs to all the new renewable energy installations.

The future of ocean energy in Spain would need key public support mechanisms, which are already outlined in the Renewable Energy Plan 2011-2020:

- Simplification of administrative procedures.
- R&D subsidies for technology development, including prototypes, resource assessment and experimental platforms.
- Investment grants for demonstration and pre-commercial projects.
- Specific and more attractive feed-in tariff system for ocean energy projects.

Relevant Legislation and Regulation

Apart from the Renewable Energy Plan and the suspension of feed-in tariffs, there are no additional changes in the current Spanish legislation regarding ocean energy: a Royal Decree from 2007 establishes the administrative procedure to apply for an authorization for electricity generation installations at sea.

RESEARCH & DEVELOPMENT

Government Funded R&D

The most important R&D project is running since 2009 partially funded by the Spanish Government within its CENIT programme. **OceanLider**, led by **"Iberdrola Ingeniería y Construcción"**, includes several R&D activities covering resource assessment, technology development of wave, tidal and hybrid systems, electrical transmission, operation, maintenance and safety systems and environmental issues. The project has a budget of €30 million (€15 million public funding) a duration of 40 months and the participation of 20 industrial partners and 24 research centres. Within the OceanLider project, companies such as Norvento Enerxía or a Cantabrian consortium coordinated by CT-Innova are developing their own concepts of wave energy converters.

A new R&D project on wave energy has been approved by the Basque Government under its ETORGAI programme in 2012. The project is also led by **"Iberdrola Ingeniería y Construcción"** with the participation of eight leading Basque companies: OCEANTEC Energias Marinas, Guascor Power, Ingeteam Power Technology, Itsaskorda, JEMA Energy, Obeki Electric Machines, Vicinay Cadenas and Corporacion ZIGOR, and the collaboration of TECNALIA as the main R&D subcontractor. The so called **UHINDAR** project, with a budget of €8 million, aims at developing a floating wave energy converter and defining the electric infrastructure and mooring systems for a complete wave energy farm. In December 2012, the first wave tank trials of a small scale device have been performed.

Participation in Collaborative International Projects

Coordination of European Ocean Energy Research

Within the context of the European Energy Research Alliance (EERA), a Joint Research Programme (JP) on ocean energy was launched in 2011, with the active participation of Spain through the involvement of TECNALIA and CTC as an associated partner since 2012. The **EERA Ocean Energy JP** is based around six key research themes: Resource, Devices and Technology, Deployment and Operations, Environmental Impact, Socio-economic Impact and Research Infrastructure, Education and Training. Spain is participating in all of the Research Themes and TECNALIA is leading the "Deployment and Operation" theme together with the German centre Fraunhofer IWES.

MARINET - Marine Renewables Infrastructure Networt - is a €9 million EU-funded initiative to provide access to test facilities in specialized marine renewable energy centres across Europe. MARINET supports testing of concepts and devices in areas such as wave energy, tidal energy, offshore wind energy and environment. The network consists of 42 testing facilities at 28 research centres in 12 countries. In Spain, **EVE and TECNALIA** are key partners in this initiative: TECNALIA is offering its Electrical PTO lab testing facilities, and EVE is offering its Mutriku OWC plant and BIMEP testing facilities. Further information: www.fp7-marinet.eu
The Spanish marine renewable energy sector has begun to benefit from MARINET:

- A collaborative project on corrosion was approved under the first MARINET call. The project deals with the assessment and mitigation of marine corrosion in metallic components for marine energy devices and is led by **CTC** with the participation of CSIC-CENIM and TECNALIA.
- **CT-INNOVA** has tested a pendulum wave energy device, developed within the OceanLider project, in the wave tank of Aalborg University.
- **EnerOcean** has tested sensor encapsulations for tidal devices installing 12 prototypes at Fraunhofer IWES, in Helgoland. EnerOcean has also supported the testing of the W2Power combined wind and wave concept through model testing at the University of Edinburgh curved wave tank, in the framework of long term collaboration with a Norwegian company that will continue with additional testing during 2013.

Participation in tidal energy projects

During the initial months of 2012 two projects related to tidal energy with a relevant participation of the Spanish SME **EnerOcean** have been finished:

- Eurostars E!4449 Q-Sail focused on the qualification of a tidal energy device based on sails. EnerOcean role was mainly in the first installations sites assessment and in the *marinization* and reliability aspects of the design. EnerOcean was supported by University of Cadiz and University of Málaga during the three years of this project.
- FP7 Capacities project Tidalsense (SME-2008-1 call, GA 232518), in which EnerOcean had a role as development steering end user and provided the theoretical basis for a remote structural health monitoring system for tidal energy devices.

EnerOcean is also participating in TidalsenseDemo (a FP7 project for SMEs funded in the 2011 call). It is a €3 million demonstration project, in which the results of the previous research project Tidalsense will be demonstrated in working tidal devices. EnerOcean is one of the leading companies of a 12 entities consortium coordinated by InnotecUK, and that includes also the University of Cadiz. The project started in February 2012. In November 2012, EnerOcean participated in the sensor installation in Nautricity prototype, which will be installed at the European Marine Energy Centre (EMEC)in January 2013.

Spanish leadership in offshore multi-purpose platforms

With the leadership of the Spanish company **Acciona Energia**, the European **MARINA-Platform** project is dealing with the evaluation of multi-purpose platforms for marine renewable energy and plan to produce a set of design and optimisation tools addressing, inter alia, new platform design, component engineering, risk assessment, spatial planning, platform-related grid connection concepts, all focussed on system integration and reducing costs. These tools will be used to produce two or three realisations of multi-purpose renewable energy platforms. The MARINA-Platform project started in January 2010 with the support of the European Commission through the seventh framework programme and will run during 54 months. Further information at www.marina-platform.com

PLOCAN, the Oceanic Platform of the Canary Islands, is leading the **TROPOS** project awarded with €6.6 million under the European call "Ocean of Tomorrow" in 2011. The objective of this project is to design multi-use offshore platforms where ocean energy plays a key role. Further information at www.troposplatform.eu

The Spanish company **AWS Truepower** is leading the **H2OCEAN** project aimed at developing a wind-wave power open sea platform equipped for hydrogen generation with support for multiple users of energy and uses such as multi-trophic aquaculture. The project started in January 2012, will run for 3 years and is also funded under the Ocean of Tomorrow 2011 call. Further information at www.h2ocean-project.eu

TECHNOLOGY DEMONSTRATION

Operational Ocean Energy Projects

The Biscay Marine Energy Platform – bimep – provides wave energy device manufacturers with facilities to validate their designs and to test their technical and economic feasibility. The Basque coast, and specifically the location of bimep off the coast of Armintza (Bizkaia), offers suitable wave conditions for device testing and a relatively low exposure to extreme waves that could damage the prototypes. Bimep occupies a 5.3 km^2 marked area excluded for navigation and maritime traffic, and located at a minimum distance of 1,700 m from shore, close enough for fast access to deployed devices. The total power of 20 MW is distributed over four offshore connection points of 5 MW each at 50-90 m water depths. Once the administrative authorisation for the installation was granted, in November 2012, the first works started with the horizontal drilling for the installation of the submarine power cables.

▲
First works at bimep: horizontal drilling for submarine cable installation

The **Oceanic Platform of the Canary Islands (PLOCAN)** is a Public Consortium aimed to build and operate an offshore infrastructure to facilitate and accelerate the development of new oceanic technologies. PLOCAN is ruled by the Spanish Government (50%) and the Regional Government of the Canary Islands (50%). This Consortium is placed on the island of Gran Canaria. PLOCAN offers a marine test site for ocean energy converters prototypes. The submarine electrical infrastructure is being designed (expected to be installed by the end of 2013) offering the required grid connection. The initial capacity is 15 MW with a future extension planned up to 50 MW by 2020. Main technologies on testing will be related to waves and offshore wind conversion. PLOCAN provides facilities to raise public funds aimed to develop innovative projects in the test site:

- **INNPACTO WAVE ENERGY (IWE)** is a project partially funded by the Spanish Government (2010-2013) and lead by the Spanish company PIPO Systems. Its main aim is to extend the concept of APC-PISYS technology looking for new applications. As expected, the first prototype was successfully deployed in October 2012 at PLOCAN's test site (Gran Canaria) for operational assessment.

- **UNDIGEN** is a project partially funded by the Spanish Ministry of Economy and Competitiveness (2011-2013). The Spanish company WEDGE GLOBAL leads the consortium formed by FCC, CIEMAT and PLOCAN. UNDIGEN is aimed to design, build and deploy a new wave energy converter prototype with a capacity of 150 kW. After completion of the mechanical and electrical design phase during 2012, as well as the studies related to the operation site, deployment is expected by October 2013.

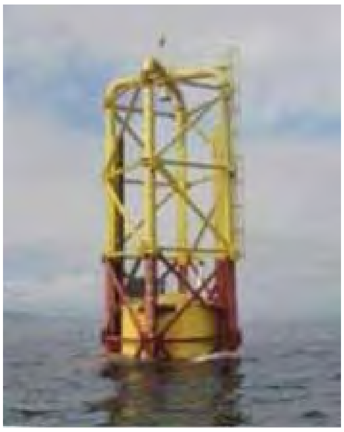
Both prototypes will have grid connection by the end of 2013 when the electrical infrastructure of PLOCAN is available.

New Developments

Ocean Power Technologies (OPT) is developing a new wave energy device (PowerBuoy®) in the Spanish coast under the WavePort EU project. In this project, OPT is collaborating in a consortium with University of Exeter, UK Intelligent Systems Research Institute, Fugro Oceanor, Wave Energy Centre (WavEC) and Degima SA. The project will build, deploy and demonstrate a commercial scale PowerBuoy® wave energy converter with an innovative Real Time Wave by Wave Tuning System. Forward knowledge of the approaching wave-train delivered by the prediction system will allow advanced control of the PowerBuoy®, recovering more energy from the ocean and substantially improving the device efficiency. This will drive down the levelized cost of energy. The project has progressed well and the consortium forecasts deployment of the PowerBuoy and completion on the sea trials during 2013 and 2014.

Abengoa (MCE: ABG), an international company that applies innovative technology solutions for sustainable development in the energy and environment sectors, has set up a new business unit for ocean energy: **Abengoa Seapower.** One of the first activities of Abengoa Seapower has been its participation in the launch of Nautimus, the first ocean energy engineering firm. Nautimus, based in Scotland, is the world's first engineering services company dedicated to wave and tidal energy. It has been established by Vattenfall, with support from Babcock and Abengoa. The company will fulfil the engineering, procurement, integration and construction (EPC) needs of wave power and tidal stream projects on behalf of utility clients.

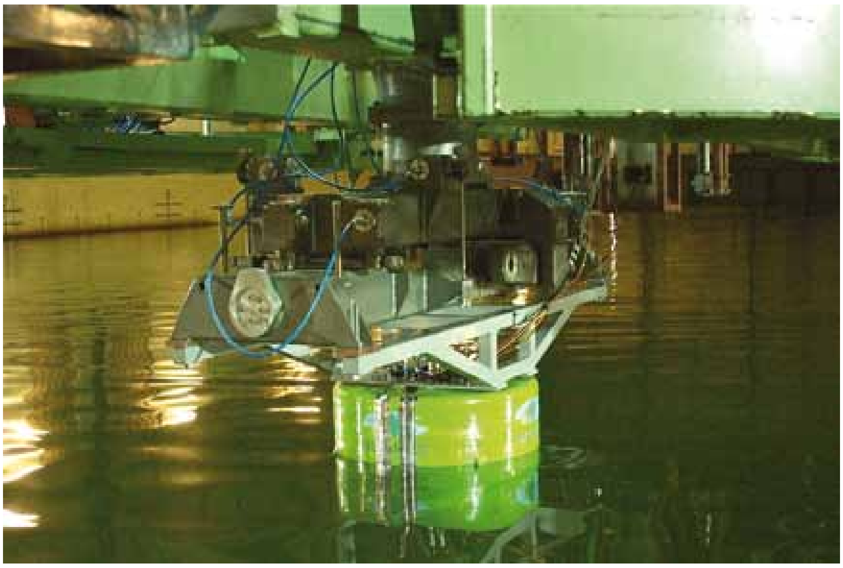
Galicia Mar Renovables (GMR): During 2009, GMR tested in Ares Sea (A Coruña) a scaled 1:10 prototype of its wave energy converter: a floating point absorber with mechanical PTO. The next steps were the development and installation of a full-scale device in 2010 and a preindustrial prototype in the summer of 2011. This prototype generated 184 kWh with an installed capacity of 250 kWh during some trials without optimal sea conditions. These tests were partially funded by the Spanish Ministry of Industry, Energy and Tourism. In 2012, GMR has started the consenting process to install two wave energy farms in Ferrol and Gijón, including an agreement between GMR and Instituto Enerxético de Galicia (INEGA). The Ferrol wave power plant is expected to be in operation in 2014.



GMR preindustrial buoy

Artist impression of a GMR wave power plant

The Ukrainian company KROK-1 has started the first steps for the installation of a wave power plant in Spain. The so called **VOWEPP project** is based on a wave energy concept with a range of relevant differences to other existing concepts and has been patented in Ukraine (patent Nº56481). It consists of a floating device with relative movements produced by hydrodynamic pressure that creates a torque on working shafts connected to an electrical generator. The VOWEPP project has as main advantages a flexible energy-absorbing system that constantly changes its parameters under the influence of incoming waves of different period and height and high reliability in strong sea storms. These advantages lead to high efficiency conversion rates with low material use (up to 100 kg per kW) and low level of investment costs and cost of energy. More information available at www.vowepp.com.



Tank testing of OCEANTEC wave energy device

ITALY

Gerardo Montanino
GSE

INTRODUCTION

The Italian increasing interest in the exploitation of wave and tidal technology to produce clean and renewable energy can be recognized either in some Government initiatives (e.g. the higher incentive for such sources) or in the research activities.
Mainly universities and companies specialized in research and innovative designs are involved in R&D in this field, thanks to which Italy is at forefront in research, development and demonstration at a prototypal level.
The offshore wind farm production is also supported through a special support mechanism.

OCEAN ENERGY POLICY

Strategy and National Targets

The new Ministerial Decree on renewable energy sources (DM 6 July 2012) reviews the support schemes (till now based on feed-in tariffs and green certificates) for grid connected renewable energy power plants (non PV). The new Decree concerns plants put into operation since 1 January 2013 (with capacity ≥ 1 kW).

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

In general, the Decree grants a fixed tariff plus, in some cases, a specific premium, to incentive net electricity fed into the grid. The fixed tariff is different according to each source, technology and capacity range considered. Power plants with a capacity > 1 MW can only receive the incentive (fixed tariff minus electricity hourly zonal price, plus premiums if foreseen). Power plants with a capacity ≤ 1 MW can receive, instead of the incentive, a feed-in tariff composed by the fixed tariff plus, in some cases, a specific premium.

In the Dutch Auctions the maximum requested value of the tariff cannot be higher than a 2% discount of the reference value and the minimum value cannot be lower than a 30% discount of the reference value.
The incentives last for the average conventional plant life of each typology of power plant.
All the support schemes are managed by GSE (the Manager of Energy Services, a governmental company that provides incentives).
New, fully reconstructed, reactivated or empowered wave and tidal energy power plants can access directly to incentives if their capacity is not greater than 60 kW, otherwise they must apply for access to Registries.

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

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

For wave and tidal energy power plants, the total annual capacity (MW) eligible to access to Registries from 2013 to 2015 and so to obtain the incentives is indicated in the below table:

	2013	2014	2015
Wave and tidal energy	3	0	0

If the total installed capacity in a certain year is less than the capacity to be supported in that year according to the Decree, the residual capacity can obtain the incentives in the following year.

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

For new wave and tidal energy power plants entering into operation in 2013, the incentives are defined as follows:

SOURCE	CAPACITY (KW)	CONVENTIONAL PLANT'S LIFE (YEARS)	FIXED TARIFF €/MWH
Wave and tidal energy	$1 < P \leq 5000$	15	300

For wave and tidal energy power plants entering into operation in 2014, the value of the fixed tariff is curtailed of 2%. For plants entering into operation in 2015, the tariff is curtailed of 2% compared to that in 2014.

RESEARCH & DEVELOPMENT

Universities are currently the key players involved in research regarding the exploitation of waves, tidal currents and river currents to produce energy.

Government Funded R&D

A list of the Italian Government funded R&D projects along with a brief description regarding the objectives of each project is given below:

- **National project "Evaluation of Effective Productivity of a Floating System for Energy Generation from Mediterranean Saw Wave"(2011-2012).** Politecnico di Torino (POLITO) and ENEA signed a special contract in the frame of the Italian national agreement between ENEA and Ministry of Economic Development on the National Energy Research Set Plan. The aim of the agreement between POLITO and ENEA is to evaluate the effective productivity of a floating system for sea wave energy conversion.

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

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

Participation in Collaborative International Projects

SINGULAR: Smart and Sustainable Insular Electricity Grids Under Large Scale Renewable Integration (FP7-ENERGY-2012)

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

TECHNOLOGY DEMONSTRATION

The public/private consortium SEAPOWER Scarl, formed by a private company and the University of Naples, thanks to the collaboration between ADAG applied research group of Department of Aerospace Engineering, University of Naples "Federico II" and Eng. Nicola Giorgio Morrone, developed one of the most attractive projects of the last period in the field of renewable energy production using marine sources, named GEM: *The Ocean's Kite* (see: www.dias.unina.it/adag/ select research, renewables and then GEM)

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

Finally, Polytechnic of Turin has developed a small demonstration unit for wave energy production named ISWEC.

GEM project

The patented concept consists of a submerged floating body linked to the seabed by means of a tether. This hull houses electrical generators and auxiliary systems. Two turbines are installed outside the floating body and are exposed to the external currents.

Due to a relatively safe and easy self-orienting behaviour, GEM, The Ocean's Kite, is a good candidate to solve some problems involved with oscillating and reversing streams, typical of tidal current. An additional advantage of its configuration is related to the possibility of avoiding the use of expensive submarine foundations on the seabed, because these are replaced with a flexible 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 on two different models has been carried out in the towing tank of the Department of Naval Engineering at the University of Naples.

The models tested were completely instrumented so that a dynamic behaviour and the off-nominal working conditions were investigated.

The real scale prototype system of 100 kW with 5 knots of water current speed has been built and has been deployed nearby Venice in a very slow speed current of about 3 knots, downscaling the power to 20 kW.

This prototype has been built by a consortium of Venetian companies thanks also to a financial contribution of Veneto Regional Authority.

The real field test has demonstrated the fully correspondence of the system behaviour with respect to what had already been measured on the 1:5 model during the test campaign in naval towing tank.

GEM: Artist impression and real scale prototype

FRI – EL SEA POWER System

Sea Power is a new groundbreaking project which consists of a vessel or pontoon, moored to the 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 diminish their maintenance. The electric generators transform the power carried by the transmission lines into electrical energy, which can be directly fed into the grid through an undersea cable, connecting the individual floating structures to a submarine hub, which in turn is 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, a 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 if the system works well in real conditions.
In July 2008, a small-scale of the 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 will be designed to be installed in rivers.

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 consists of a submerged vertical-axis turbine for exploitation of marine currents installed in the Strait of Messina, 150 metres off the coast of Ganzirri, since 2002. The realization of the Enermar prototype has been financed by Ponte di Archimede Company, together with a 50% fund paid by the Sicilian Region

Administration (Regione Siciliana), in the framework of European Union Structural Funds. This project has been disseminated among the developing countries in which the United Nations Industrial Development Organization (UNIDO) operates and three first countries that expressed interest. These countries were the People's Republic of China, the Philippines, and Indonesia. A joint-venture was created, under the auspices of UNIDO, between "Ponte di Archimede" and the Indonesian Walinusa Energy Corporation.

A prototype is being built and it will placed on the Lomboc Island (the island immediately at east of Bali), where it could feed energy to a small village. The Indonesian plant will have blades length 7 m, (chord 0,4 m) and diameter 5 m (intercepted area 35 m^2). The power could be about 120-150 kW.

Ponte di Archimede International has signed an agreement with the Dutch company Bluewater to develop the Bluetec device with the scientific and technological support of ADAG Group from University of Naples "Federico II". This floating device will hold four Kobold turbines for a total power of about 1 MW and will represent a single unit of a possible farm made by several Bluetec systems. Towing tank experiments have been carried out both at Wageningen facilities and at University of Naples.

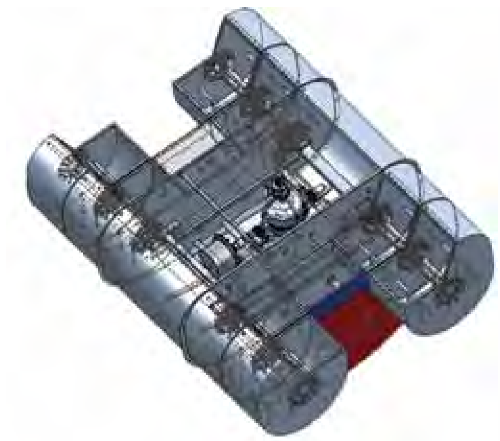
ISWEC Project

Sea waves are one of the most interesting and well distributed renewable energy sources in the world. At the current state of the art, all the existing sea wave energy conversion systems are designed to operate offshore, mainly in the oceans where the waves' height is definitely high. In the Mediterranean Sea, waves are generally low, except under particular meteorological conditions. Thus, it is necessary to develop devices that can exploit other properties of the waves instead of their height, like wave slopes.

The mechanical conversion system, called ISWEC, that will be used for the development of the project has been analysed by Politecnico di Torino and results show that the system possesses good potential for energy conversion.

ISWEC device is composed mainly of a floating body with a slack mooring to the seabed. The waves tilt the buoy with a rocking motion that is transmitted to the gyroscopic system inside the buoy. The gyroscopic system is composed of a spinning flywheel carried on a platform. As the device works, the gyroscopic effects born from the combination of the flywheel spinning velocity $\dot{\varphi}$ and the wave induced pitching velocity $\dot{\delta}$ create a torque along the ε coordinate. Using this torque to drive an electrical generator, the extraction of energy from the system – and therefore from the waves – is possible.

Trials at various levels will be carried out: in the first phase, a set of "dry tests" will be carried out on a controlled position mobile platform; in the second phase, a series of tests will be carried out in a tank, with suitably generated and controlled waves. Finally, the system will be placed and tested on Pantelleria Island.



ISWEC drawing and scaled prototype in testing site

NEW ZEALAND

John Huckerby
Aotearoa Wave and Tidal Energy Association

INTRODUCTION

Although there has not been a high level of public activity this year, the year was notable for three reasons:
1. The first full deployment of Wave Energy Technology – New Zealand's ½-scale 'MEDF' device at Moa Point in Wellington (27 May – 17 June 2012)
2. The first full deployment of Wave Energy Technology – New Zealand's ½-scale 'US' device at the Northwest National Marine Renewable Energy Centre's test site of Yaquina Head, Oregon (23 August – 5 October 2012)
3. The award of a NZ$ 940,000 grant over 3 years from the Marsden Fund to Dr. Ross Vennell of Otago University for tidal energy research

OCEAN ENERGY POLICY

Strategy and National Targets

The current Government introduced its NZ Energy Strategy in August 2011, which has an aspirational target of 90% renewable energy generation by 2025, supported by the National Policy Statement on Renewable Electricity Generation, which came into effect in May 2011. The Government has also set a greenhouse emissions reductions target to reduce emissions by 50% from 1990 levels by 2050. Although the NZ Government was a signatory of the Kyoto Protocol, it has recently announced that it will not sign up to a second phase of the Kyoto Protocol.
There are no market stimulation incentives or other support for renewables, including marine energy.

Main Public Funding Mechanisms

The 4-year Marine Energy Deployment Fund (2008 - 2011) funded six deployment projects, of which 4 were wave projects and 2 were tidal current projects. Three of the projects are still active and eligible to receive funds.

Apart from MEDF, principal public funding is for R&D through either direct Government funding or other public funding sources. Two Government-funded R&D projects ended in September 2012 but subsequently Dr. Ross Vennell at Otago University was awarded $940,000 from the Marsden Fund to research tidal array capacity and arrangements.

Relevant Legislation and Regulation

Consents to undertake marine energy projects in the Coastal Marine Area (to the 12 nautical mile limit) are granted under the Resource Management Act 1991 and its amendments. This is environmental legislation. There is no allocation regime for marine energy.

The first marine energy consents in New Zealand were activated by WET-NZ in May 2012.

However, there have been some changes to consenting practices in New Zealand's Exclusive Economic Zone (beyond the 12 nautical mile limit) during 2012.The Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 (the EEZ Act) became law on 3 September 2012. The EEZ Act will come into force when the regulations are in place or no later than 1 July 2014. These new regulations specifically cover new uses of the ocean, not covered by existing environmental legislation. However, the new regulations are unlikely to affect marine energy projects in the near future, as projects are likely to be closer to shore. There have been no other significant updates to legislation or regulation during 2012.

RESEARCH & DEVELOPMENT

Government Funded R&D

The principal Government funding has been to a collaborative R&D research programme called Wave Energy Technology – New Zealand (WET-NZ), collaboration between Industrial Research Limited (IRL) and Power Projects Limited (PPL). A ½-scale device 20 kWp, called the MEDF device (named after the fund, which enabled its fabrication and deployment), was deployed off Moa Point, Wellington, New Zealand (Figure 1a) in May – June 2012 (after a 3-month trial off Akaroa Heads in late 2011). Due to problems with the moorings the device was removed after 3 weeks and analysis is being completed to redesign the moorings for redeployment in 2013.

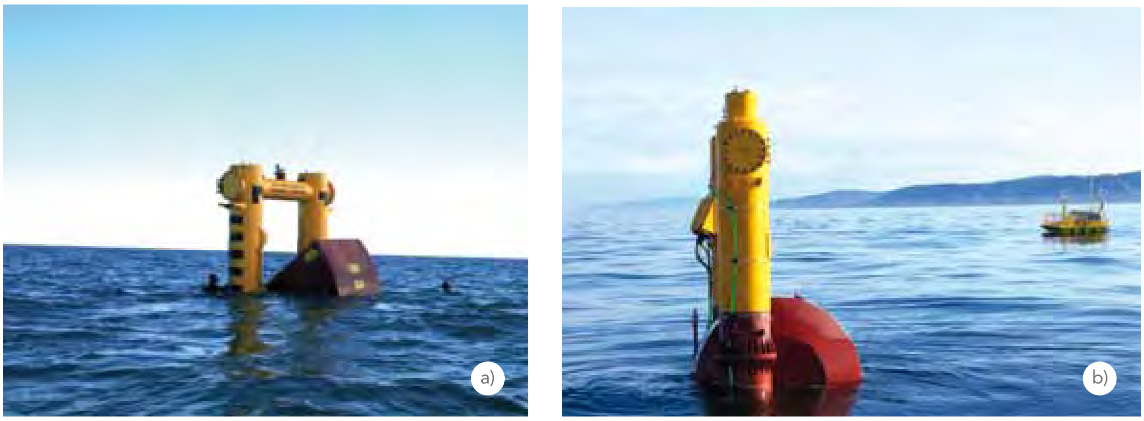


FIGURE 1: a) WET-NZ's MEDF device off Akaroa Heads (2011) and b) its US device at the NNMREC test site, Oregon (August 2012)

Participation in Collaborative International Projects

In 2010, WET-NZ, together with US project manager, Northwest Energy Innovations, was awarded a grant from US Department of Energy to build and deploy a 2nd generation ½-scale 20 kWp device in Oregon (Figure 1b). The US device was assembled in Newport, Oregon, in August 2012 and deployed at the Northwest National Marine Renewable Energy Centre's test site off Newport, Oregon for six weeks from 23 August to 5 October.

In April 2012, the Aotearoa Wave and Tidal Energy Association (AWATEA) hosted its 6th Annual Conference with the theme of "Blue Energy: from International Vision to Reality". The conference was run in conjunction with a Marine Energy Mission, organized by the British High Commission in Wellington, which brought 12 UK companies to New Zealand. Subsequently, the NZ Ministry of Science and Innovation awarded 7 travel grants to New Zealand companies to visit the UK companies in the UK and to establish working links.

TECHNOLOGY DEMONSTRATION

Operational Ocean Energy Projects

As noted above, the only devices that have been deployed this year are WET-NZ's ½-scale device at Moa Point, Wellington and a similar but not identical WET-NZ ½-scale device deployed at NNMREC's test site off Newport, Oregon.

SWEDEN

Maja Wänström
The Swedish Energy Agency

INTRODUCTION

During 2012, ongoing Swedish research, development and demonstration efforts related to ocean energy have continued to progress. While the financial climate and the high costs related to new energy conversion technology constitute challenges for developing companies, the area of ocean energy conversion has attracted the attention of universities and technical research institutes. Access to public funding remains vital to all stages of the ocean energy research and innovation process in Sweden.

The forefront of Swedish ocean energy technology development and demonstration is the consented 10 MW wave power demonstration project at Sotenäs, which commenced late 2011. During 2012, the developer Seabased Industry AB has undertaken preparation activities for site development, wave energy converter construction and grid connection for the first 1 MW phase of the demonstration park.

OCEAN ENERGY POLICY

Strategy and National Targets

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

In order to realize the vision and implement the EU Renewables Directive, the following national target for renewable energy and efficient use of energy in Sweden by 2020 has been set:

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

During 2012, EU member states have for the first time reported their performance under the Renewables Directive. The forecast in Sweden's report shows that the country is in line to achieve its target by a slight margin.

Support Initiatives and Market Stimulation Incentives

Fundamental to the long-term Swedish energy policy are general economic policy instruments such as carbon tax, international emissions trading and tradable certificates for renewable electricity. From the perspective of ocean energy technology development, the renewable electricity certificate system (a tradable green certificate system) is the most relevant policy instrument.

The electricity certificate system is a market-based support system for cost-effective expansion of electricity production from renewable sources. By design, the system does not specifically target a particular renewable electricity conversion technology, i.e. is technology neutral. Electricity certificates are issued to those who produce electricity from one or more renewable energy sources, or from peat, and who have had their production plants approved by the Swedish Energy Agency. To date, certificates have been issued to producers of electricity from biofuels and peat, wind power, hydro power and solar electricity. While wave energy is one of the renewable energy sources for which producers would be eligible for certificates, none have been issued so far.

In 2011, Sweden and Norway entered into an agreement to form a joint electricity certificate market, which has been in operation since the beginning of 2012. Together with Norway, annual production from renewable sources in 2020 shall have increased by a further 13,2 TWh relative to production in 2012.

Main Public Funding Mechanisms

The main public funding mechanism for research, business- and technology development and technology demonstration are Swedish governmental agencies tasked to support academic and private sector R&D in the various stages of innovation. There is currently no one funding body with a dedicated funding scheme that targets ocean energy. Nonetheless, there are a number of governmental agencies from which researchers and developers can apply for funding.

- The Swedish Research Council, www.vr.se, which, among other things, is tasked to fund fundamental research and expensive equipment for research purposes within a large number of topic areas.
- The Swedish Energy Agency, www.energimyndigheten.se, is the Swedish agency responsible for facilitating a sustainable energy system in Sweden. As such, the agency funds research, business- and technology development and technology demonstration which is relevant for the sustainability of the energy system and the sustainability for the energy industry sectors.
- The Swedish Governmental Agency for Innovation Systems (VINNOVA), www.vinnova.se, supports business- and technology development. VINNOVA also acts as contact point for the European Community FP7 for research and development.

In addition, regional authorities are able to grant funding to varying extents.

Relevant Legislation and Regulation

The Swedish Agency for Marine and Water Management is currently working to implement a new system for marine spatial planning. Provisions for the plans will be incorporated into a new law which is expected to come into force during 2013.

In order to establish test sites for research and development and sites or parks for technology demonstration in Swedish marine environments, permits must be obtained from the local County Administration Board. The permits are granted after an extensive environmental impact assessment court procedure.

Relevant Documents Released

Sveriges nationella handlingsplan för främjande av förnybar energi. Available at http://www.regeringen.se/

The Electricity Certificate System 2012, ET2012:32. Available at the webpage of the Swedish Energy Agency www.energimyndigheten.se.

RESEARCH & DEVELOPMENT

At present there are no national programmes targeting ocean energy research and innovation. Instead, researchers and developers apply for project funding.

Uppsala University

The Centre for Renewable Electric Energy Conversion at Electricity Uppsala University has been active in ocean energy research related to linear generator wave power technology and vertical axis low speed marine current technology since early 2000. Wave energy activities are focused on a full system approach including system modelling and control, generator and buoy design and model development. Marine current research projects include resource potential studies as well as system modelling from water currents.

In order to facilitate field testing and verification of research results, two research sites are operated by Uppsala University; the Lysekil wave power research site that has been in operation since 2006 and the Söderfors marine currents research site. At the Lysekil wave power research site wave climate can be monitored and environmental impact studies performed and the site has permits for up to 10 WECs that are operated for research purposes. The site is currently not grid connected. The Söderfors marine currents research site is located in Dalälven river between two hydropower plants. The research site is currently being developed to enable in-river testing of a vertical axis and direct drive generator device for low speed marine currents.

Chalmers University of Technology

At Chalmers University of Technology ocean energy research projects on mooring design, power transmission and mooring fatigue started up in 2011. The research is being carried out at the departments of Shipping and Marine Technology and Energy and Environment in collaboration with the Ocean Energy Centre (OEC), which was also initiated in 2011.

OEC is an innovation platform for collaboration, cooperation and communication among ocean energy stakeholders hosted by the Department of Shipping and Marine Technology at Chalmers University of Technology. OEC is a partnership between the Swedish development companies Minesto, Ocean Harvesting Technologies, Vigor Wave Energy and Waves4Power, the technical research institutes SP and SSPA, Chalmers University of Technology and the Region of Västra Götaland, which is the main financial partner.

Government Funded R&D

Several research and development projects with public funding have been running during 2012:

CFE II – Center for Renewable Electric Energy Conversion II

CFE II is an extensive research project at the Center for Renewable Electric Energy Conversion at Uppsala University, in which a total of 14 graduate students carry out research related to wave power, vertical axis wind power and marine currents. CFE II is funded by the Swedish Energy Agency, the Swedish Governmental Agency for Innovation Systems, Uppsala University and the utilities Statkraft and Vattenfall.

Buoy-to-grid

Buoy-to-grid is an applied development project, financed by the EU European Regional Development Fund and the Region of Västra Götaland. It aims to support the development of common technical solutions for power, signal and communication transmission, from the power take-off at the offshore installation to the main onshore power grid. The project is led by the technical research institute SP and carried-out in cooperation with the OEC partner organizations.

Mooring design and energy capture

The research project develops numerical models that can analyse how the mooring set-up alters the energy capture of wave energy devices. It is financed by the Region of Västra Götaland and carried-out by researchers at the Department of Shipping and Marine Technology at Chalmers University of Technology, in collaboration with the OEC development companies.

Power transmission

The research project focuses on the power generation and control systems in wave energy devices and aims at finding optimal designs. It is financed by the Region of Västra Götaland and carried-out by researchers at the Division of Electric Power Engineering at Chalmers University of Technology, in collaboration with the OEC development companies.

Durability analysis of cables and moorings used in ocean energy systems

The research project focuses on fatigue challenges in electrical cables and moorings related to wave energy applications. It is financed by the Swedish Energy Agency and carried out by researchers at the Department of Shipping and Marine Technology at Chalmers University of Technology, in collaboration with the OEC development companies.

Blue Energy

Blue Energy is an industry study project that aims to develop a proposal for a national strategic research and innovation agenda for ocean energy, focusing on wave and tidal. The project is led by Chalmers University of Technology and carried out as a collaborative initiative between industry actors. Blue Energy is funded by the Swedish Governmental Agency for Innovation Systems.

Development and performance trials of a tidal energy device

The project involves design, construct, test and deployment of a 1:4 scale device developed by Minesto at Strangford Lough in Northern Ireland. The project is partly funded by the Swedish Energy Agency.

High efficiency wave energy converters CorPower Ocean

The project is proof-of-concept verification of a wave power concept developed by CorPower Ocean and is carried out in collaboration with the Royal Institute of Technology, in Stockholm, WavEC in Lisbon, Portugal, and MARINTEK in Trondheim, Norway. The project is partly funded by the Swedish Governmental Agency for Innovation Systems.

Participation in Collaborative International Projects

The Uppsala University Center for Renewable Electric Energy Conversion is participating in the Scandinavian ocean energy network Statkraft Ocean Energy Research Programme and a partner in the European KIC InnoEnergy. Uppsala University is also a partner in the EU project SOWFIA that aims to provide recommendations for approval process streamlining and helping to remove legal, environmental and socio-economic barriers to the development of offshore power generation from waves.

The developer Minesto is a partner in a joint development proposal which has been submitted together with a UK-based tidal energy developer and Norwegian and Portuguese partners. The company has also an ongoing R&D project with Bangor University related to sites in Wales.

TECHNOLOGY DEMONSTRATION

Operational Ocean Energy Projects

The Sotenäs wave power demonstration project

Seabased Industry AB is developing and constructing complete system solutions for ocean wave energy, i.e. equipment to absorb energy in ocean waves, convert it to electricity and deliver the electric power to the grid. The Seabased activity is closely related to Uppsala University where the research of the concept was initiated and which is now being developed by Seabased. The Sotenäs Project started at the end of 2011, and it will result in the largest power plant built in the world for wave energy. The project is developed in two stages, the first stage will be built during 2012 and 2013. The second stage starts after stage one has been evaluated. Total installed power in the first stage is 1 MW, and the full power plant will have an installed power of 10 MW. The Sotenäs Project is partly funded by the power company Fortum and partly funded by the Swedish Energy Agency.

AUSTRALIA

John Wright
Commonwealth Scientific and Industrial Research Organisation (CSIRO)

INTRODUCTION

Ocean energy development continues to be active in Australia. There are 19 identifiable ocean energy developers in Australia consisting of 11 wave and 8 tidal. Currently there are four major government-supported commercial or pilot scale installations under construction, together with plans for other ocean energy activities in both wave and tidal at various stages of development.
Australia has very large potential ocean energy resources, which have been confirmed in a study conducted by CSIRO and syndicated with industry and government[1]. This study was publically released in July 2012. The study concludes that to capitalise on those resources will require overcoming problems such as distance to the existing grid from the resource centres, competition with other low emission technologies on initial and lifetime cost, meeting the investment criteria of the financial sector and demonstrating the environmental credentials of ocean energy.

OCEAN ENERGY POLICY

Strategy and National Targets

In November, the Federal Government released The Energy White Paper 2012, Australia's energy transformation[2]. This paper sets out a strategic policy framework to address the challenges in the energy sector and position Australia for a long term transformation in the way energy is produced and used. While the white paper acknowledges the magnitude of Australia's ocean energy resources, there is little direct reference to the technology and it is generally referred to in combination with other forms of renewable energy.

The Federal Government has specified a renewable electricity supply target of 20% by 2020. This is broken into large scale devices and small scale systems, focused mainly on rooftop PVs. The large and small scale systems attract renewable energy certificates which can be traded to retailers who have to purchase the renewable energy[3]. There are no specific allocations for different technologies within the 20% target.

In 2011, the Federal Government introduced legislation for an initial carbon tax of $23/t of CO_2 on the top 200 "polluters" from July 2012. The carbon tax will transition in 2015 to a carbon emissions trading scheme.

Over time, the above mentioned measures should assist to improve the economic case for ocean energy development in Australia.

Support Initiatives and Market Stimulation Incentives

The Federal Government has established the Australian Renewable Energy Agency (ARENA) to bring together a number of previous renewable energy schemes and create new renewable energy investment totalling $3.2 billion[4]. ARENA offers part funding for research, development, demonstration and commercialisation to be integrated and will provide continuity of support for the full range of developing

[1] http://www.csiro.au/ocean-renewable-energy
[2] http://www.ret.gov.au/energy/facts/white_paper/Pages/energy_white_paper.aspx#what
[3] http://www.orer.gov.au/Certificates/certificates
[4] http://www.ret.gov.au/Department/Documents/clean-energy-future/ARENA-FACTSHEET.pdf

renewable energy technologies, including ocean energy. Applications in the form of expressions of interest and "measures" aimed at promoting renewable energy in Australia can be made at any time. There are no limits on funding amount requests or proportion of project costs sought from ARENA.

Relevant Documents released

Documents relevant to the development of ocean energy in Australia include the Energy White Paper (2.1) and the CSIRO study "Ocean Renewable Energy: 2015 – 2050: An Analysis of Ocean Energy in Australia".

RESEARCH & DEVELOPMENT

Government Funded R&D

The majority of ocean energy research is done through the Australian university research system financed largely by the Australian Research Council (ARC). A number of Universities are involved in ocean energy research. These include the University of Tasmania's Australian Maritime College, the University of Wollongong, the University of New South Wales Water Research Laboratory, the University of Sydney and spinoff companies from the University of Queensland testing facilities. This, and work by other universities, focuses on a wide range of topics of general interest in the ocean energy domain.

CSIRO's research has been focused on Australia's ocean energy resource base and the economics of inclusion of ocean energy in the technology suite in Australia out to 2050. This has been largely exploratory. The development of specific ocean energy extraction devices has not, and is not likely to be in the future, a priority for the organisation.

Industry Funded R&D

An industry association, Ocean Energy Australia (OEIA), has been formed to provide a level of coherence to pilot and commercial scale developments in Australia[5]. OEIA currently has eleven industry members. OEA's vision is to "help Australia meet its clean energy future through a thriving and vibrant ocean energy sector". OEA aims to progress in three initial areas, namely a public education initiative, the preparation of ocean energy development strategy and building best practice for ocean energy governance in Australia.

There are 19 companies active in Australia, varying in scale from concept development to demonstration to commercial deployment. The industry sums invested are commensurate with the scale of achievement. Those companies which have been successful in gaining government grants have had to invest at significant scale.

Participation in Collaborative International Projects

Several Australian companies have strong links with overseas partners assisting to develop their technologies. These include Carnegie, Ocean Power Technology Australia and Oceanlinx.

At present, Australia is involved with the Ocean Energy Systems Implementing Agreement though the CSIRO. Currently a temporary (observer status) agent is being used to maintain OES links until a permanent Executive Committee member and alternative is appointed.

TECHNOLOGY DEMONSTRATION

Operational Ocean Energy Projects

Currently Australia has no commercial ocean energy projects in operation. The largest project proposed to date is a 62.5 MW Ocean Power Technologies Australia (OPTA) array (28 buoys) off the coast of Victoria. OPTA aims to install the first three "Power" buoys by the end of 2013 and will complete the 28-buoy array with "larger versions" of its modules by 2017. This is contingent on financial close for the first stages of the

[5] *http://oeia.org.au/wp-content/uploads/2012/10/OEIA_2012-2013_Membership_Packet.pdf*

$230 million project at the end of this year or early next year. The project was awarded a $66 million grant by the Federal Government in 2009, initially with the involvement of the Australian construction company, Leighton Holdings. Leighton has now been replaced by Lockheed (USA) to assist with project development and manufacturing requirements.

Carnegie Corporation has recently received a $15.5 million Federal Government grant for the $31 million Perth Wave Energy Project (Western Australia). The total project size is up to 2 MW and demonstrates Carnegie's previous smaller-scale CETO technology funded in part by the State Government of Western Australia. Five CETO units are to be deployed, with each "buoyant activator" of 11 metres diameter delivering 240 kW. Power delivery to the grid is planned for the end of 2013.

Oceanlinx has received a $4 million Federal Government grant for a $7 million project to demonstrate the operation of their "GreenWAVE" (shallow water) oscillating water column technology 4 km off the South Australian coast. Grid connection is anticipated for the end of 2013.

New Developments

In July 2012, it was announced that BioPower Systems received a $5.7 million grant from the Federal Government to develop a $15 million bioWAVE pilot demonstration project off the coast of Victoria. The project has also received funding support from the State Government of Victoria ($5 million). The bioWAVE pilot is expected to be deployed in late 2013.

The tidal company, Tenax Energy has recently signed a Memorandum of Understanding (MOU) with the Northern Territory's Power and Water Corporation to develop a 2 MW pilot plant, and a Research and Tropical Tidal Testing Centre based on the Clarence Strait near Darwin (the capital of the Northern Territory). If the 2 MW pilot plant is successful, it will be followed by a 10 MW pilot array test facility. It is intended that the testing station will be used to trial a number of different turbines and technologies in the Clarence Strait.

SOUTH AFRICA

Thembakazi Mali
SANEDI

In South Africa there is a lot going on in Renewable Energy. A number of Solar, Wind, Hydro and Biomass projects have reached financial close and some plants will be coming on stream in the next two years. However, there is very little activity on Ocean Energy and there has not been substantial investment except a couple of university research projects. Eskom is continuing to monitor the Agulhas current and they are also performing wave resource assessments at 8 locations around the south and south eastern sea board of South Africa. The Technology Innovation Agency (TIA) and Eskom launched an 'open innovation challenge' through which they hope to stimulate the development of commercially viable ocean-current-energy technologies. The open innovation challenge is looking for proven-concept proposals that are environmentally and aesthetically sensitive and have potential for technology development on a commercial scale. This challenge aims to bring the much required impetus to accelerate South African innovations and commercialise a technology. Thirty eight proposals were received from both the local and international market. Seven proposals were shortlisted for funding and potential further development. A meeting of the South African Ocean Energy Network was convened and it is expected that the network which consist of interested stakeholders will eventually be an association.

REPUBLIC OF KOREA

Keyyong Hong
Korea Ocean Research and Development Institute

INTRODUCTION

The budget and number of projects for ocean energy RD&D (Research, Development and Demonstration) continued to grow in Korea in 2012. They are mainly funded by Government programmes led by MLTM (Ministry of Land, Transport and Maritime Affairs) and MKE (Ministry of Knowledge) but the involvement from private sectors has also increased particularly in the tidal current device development. The renewable energy policy of RPS (Renewable Portfolio Standard), which applies a different REC (Renewable Energy Certificate) value to each renewable energy source, has been enacted in Korea since 2012. The Sihwa tidal barrage and Uldolmok tidal current power plants are being operated continuously though more ocean energy plants were installed and tested in Korean coastal waters in 2012. The Sihwa power plant is still in controlled operation and has produced 396,210 MWh from 1 August 2011 to 30 September 2012. About 553,000 MWh annual production is expected as it begins full operation.

OCEAN ENERGY POLICY

Strategy and National Targets

The strategic plan for ocean energy development in Korea is based on "The 3rd National Plan for Technology Development, Use and Diffusion of New and Renewable Energy", in which the national vision, long-term goal, strategy and action plan for new and renewable energy development for the period of 2009~2030 have been established. It has also proposed an establishment of laws and regulations for the efficient enforcement of the strategic plan. The action plan for ocean energy development is divided into 3 phases. In the first phase, until 2012, ocean energy RD&D is mainly funded by the Government and it focuses on the development of core technologies that are suitable to coastal area. In the second phase, from 2013 to 2020, the role of industries will gradually increase in both funding and RD&D and the technologies that are applicable in open sea will be exploited. In the third phase, from 2021 to 2030, the industries will lead commercial development for ocean energy resources and the hybrid utilisation of technologies combining multiple ocean energy resources will be activated.

Korea targets to supply 11% of national energy demand from new and renewable energy by 2030, and the ocean energy contributes with 4.7% to the total new and renewable energy supply, which amounts to 1,540kTOE.

Support Initiatives and Market Stimulation Incentives

The RPS policy as a primary promotion tool for renewable energy including ocean energy was enforced on 13 utility companies with a total capacity larger than 500MW in 2012, replacing the Feed-In Tariff (FIT) policy initiated in 2002. It requires the companies to supply 2% of total electricity production by renewable energy in 2012 and to increase its portion to 10% in 2022. The policy applies a Renewable Energy Certificate (REC) value, which varies depending on the resource type and conditions, such as distance from coastline, capacity and installation method. The REC of tidal barrage with embankment is 1.0 while the one without embankment is 2.0. The REC has not been determined for other ocean energies.

Main Public Funding Mechanisms

The public funding for renewable ocean energy is led by the two Government ministries of MLTM and MKE Economy which operate the national RD&D programme for ocean energy. MLTM supports mainly demonstration projects under the "Practical Ocean Energy Technology Development Programme". MKE funds mostly fundamental R&D projects under "New and Renewable Technology Development Programme".

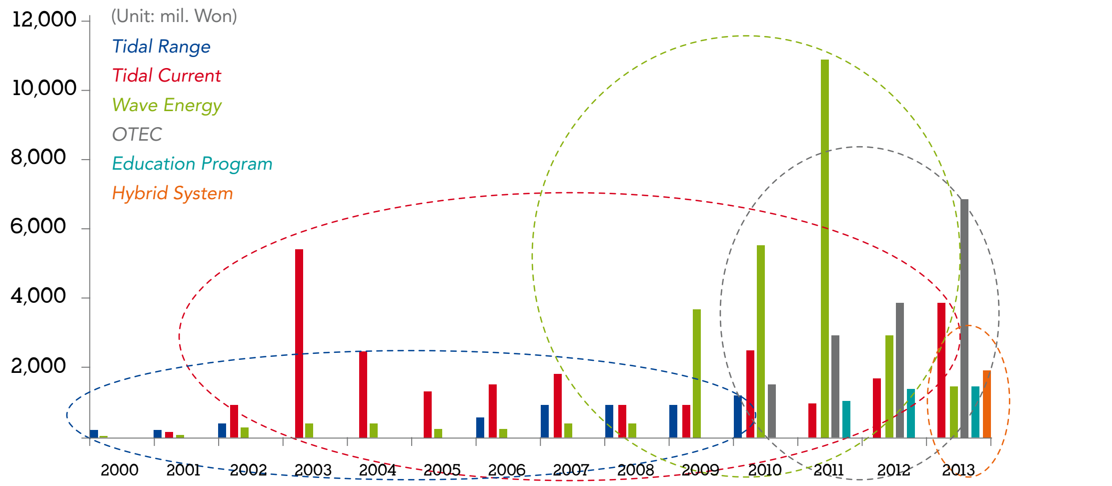


FIGURE 1: Budget of Ocean Energy RD&D Projects Funded by MLTM

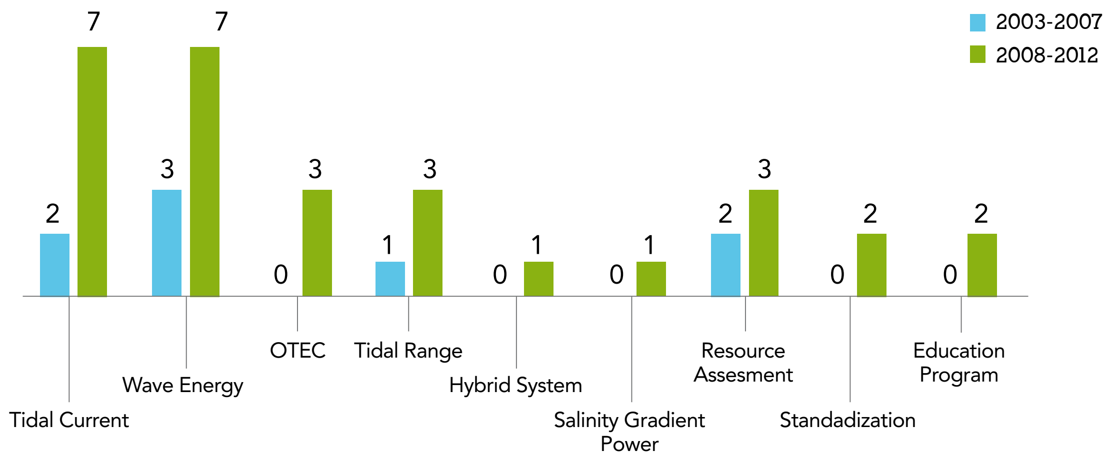


FIGURE 2: Number of Ocean Energy RD&D Projects Funded by MKE

Relevant Legislation and Regulation

The primary national acts for renewable energy development are "Framework Act on Low Carbon, Green Growth" established in 2010 and "Act on the Promotion of the Development, Use and Diffusion of New and Renewable Energy" in 1987. The former was enacted to promote the development of the national economy by laying a foundation for low carbon, green growth and by utilising green technology and green industries as new energies for growth. The latter was initiated to contribute to the preservation of the environment, the sound and sustainable development of national economy, and the promotion of national welfare by diversification of energy sources, environment-friendly conversion of the energy structure and reduction of greenhouse gas emissions. In addition, some of important national acts on energy include "Energy Act" in 2006, "Energy Use Rationalization Act" in 1979 and "Integrated Energy Supply Act" in 1991. The primary regulatory measures for marine environment protection in ocean energy development include "Framework Act on Marine Fishery Development" in 2002, which determines the Government basic policy and its directions for the national management, preservation, development and utilisation of the sea and marine resources, "Conservation and Management of Marine Ecosystems Act" in 2006, and "Marine Environment Management Act" in 2007.

Relevant Documents Released

The national strategy and roadmap for renewable ocean energy development is still based on the "RD&D Strategy 2030 for New and Renewable Energy – Ocean" and "Development of Activity Plan on Ocean Energy R&D Programme", in 2009, which are released by the MKE and MLTM respectively. The MKE will publish the "White Paper on New and Renewable Energy 2012" in early 2013. A planning report on potential test sites for wave and tidal energy devices has been prepared based on a preliminary feasibility study and a survey project to identify target sites was recommended.

RESEARCH & DEVELOPMENT

Tidal Energy R&D Projects

PROJECT (Charged By, Funded By)	TYPE OF CONVERTER	STRUCTURE	POWER CAPACITY	PROJECT PERIOD	REMARKS
Standard Turbine Design S/W (KMU, MKE)	(HAT/VAT)	(Performance Chart)	(GUI System)	2009~2012	Based on CFD
VIVEED (KIOST, MKE)	VIV Cylinder	Pile	2009~2012	2009~2012	-
Tidal Current Energy RC (KMU, MKE)	(Turbine Design)	(Underwater Design)	(Resource Assessment)	2009~2014	Joint Research Centre
In-stream Hydro System (Ecocean Ltd., MKE)	Helical Turbine (VAT)	Jacket	50kW	2010~2012	Discharge Channel of Power Plant
MW Class Tidal Current Device (HHI, MKE)	Pitch Control	Pile	>500kW	2010~2015	Sea Test in 2014
Hydraulic Turbine for Tidal Barrage (HHI, MKE)	Bulb	Caisson	7MW, 30MW	2011~2014	Applicable to Hydraulic Dam
Flexible Turbine for Tidal Current (KIOST, MKE)	Flexible Flap	-	10kW	2011~2014	Efficiency > 26%
Active Control Tidal Current System(KIOST, MLTM)	HAT / Pitch Control	-	300kW	2011~2017	Sea Test in 2016

KMU: Korea Maritime University
HHI: Hyundai Heavy Industries Co., Ltd.
KIOST: Korea Institute of Ocean Science and Technology

Wave Energy R&D Projects

PROJECT (Charged By, Funded By)	TYPE OF CONVERTER	STRUCTURE	POWER CAPACITY	PROJECT PERIOD	REMARKS
Yongsoo OWC (KIOST, MLTM)	OWC	Caisson	500kW	2003~2014	Pilot Plant in 2013
AWS with Linear Generator (Yonsei Univ., MKE)	Point Absorber	Buoy	-	2010~2013	4-sided Linear Generator
Resonant Vertical Oscillator (Gyeongju Univ., MKE)	Point Absorber	Buoy	-	2010~2013	Prototype Test in 2013
Pendulum WEC (KIOST, MLTM)	Oscillating Surge	Floating Twin Hull	300kW	2010~2016	Korea-Japan Collaboration
Cross-Flow Hydraulic Turbine (KMU, MKE)	Wave Overtopping	Caisson	-	2011~2014	Converting Wave Energy to Current Energy

Others

PROJECT (Charged By, Funded By)	PROJECT PERIOD	REMARKS
Promotion Programme for Ocean Energy Education (KIMST, MLTM)	2009~2018	MLTM programme promoting ocean energy education, research and development in universities
Efficiency Improvement Technologies for OTEC (KMU, MKE)	2010~2012	Development of working fluid and key technologies for efficiency improvement of OTEC system
Salinity Gradient Utilisation of Sea and Fresh waters (Hongik Univ., MKE)	2010~2012	Key technology development for power generation system utilising the salinity difference between sea and fresh waters at estuaries
OTEC Using Deep Ocean Water (KIOST, MLTM)	2010~2015	Cooling & heating system of 60RT in 2011 and 1,000RT in 2012 OTEC pilot plant of 20kW in 2013 and 50kW in 2015
Hybrid System of OWT and Tidal Current Converter (Inha Univ., MKE)	2011~2013	Development of fundamental technologies for hybrid power system utilising offshore and tidal current energies
Hybrid OTEC Using Plant Array (KEPRI, MKE)	2011~2014	Use of cooling water discharged from power plant Pilot plant of 10kW in 2014
Standardization of Mooring System for OES (KR, MKE)	2011~2014	Development of international standards for design and evaluation of mooring system applicable to ocean energy devices
Establishment of Infra System for Ocean Energy (KAIST, MKE)	2011~2016	Education programme for ocean energy experts in graduate school
Sea Test Bed for Ocean Energy (KOMERI, MKE)	2012~2013	Feasibility study and field survey on coastal test bed sites for wave energy converters and tidal energy devices
Standardization of OTEC (KR, MKE)	2012~2014	Development of international standards for design and evaluation of ocean thermal energy utilisation system

KIMST: Korea Institute of Marine Science and Technology Promotion
KEPRI: Korea Electric Power Research Institute
KR: Korea Register of Shipping
KAIST: Korea Advanced Institute of Technology
KOMERI: Korea Marine Equipment Research Institute

TECHNOLOGY DEMONSTRATION

Operational Ocean Energy Projects

Since the Sihwa tidal barrage power plant of 254MW capacity began its operation in August 2011, it had produced 396,210 MWh by the end of September 2013. It is expected to produce 552 GWh annually as it operates fully.

Sihwa Tidal Power Plant (254MW)

The HyTide 110-5.3 horizontal axis tidal turbine, a product of Voith Hydro with rated power of 110 kW and diameter of 5.3m, was installed in Jindo of Korea in the Spring of 2011. The site was used to test the turbine under extreme conditions. It has been tested for three months in 2012, resulting in the availability of 94% and rotor power peak of 130 kW.

▲
Installation of HyTide 110-5.3 of Voith Hydro

New Developments

The Yongsoo wave power plant, a pilot plant of 500kW OWC (Oscillating Water Column) wave energy converter which has been developed by KIOST and funded by MLTM, is being constructed at Yongsoo, Jeju of Korea. However, its completion has been delayed for more than a year, mainly because of exceptionally frequent typhoons in the region during the summer period of 2012. The construction of the caisson structure and underwater power cable will be finished in the second quarter of 2013. Then the installation of the generation equipment will be followed in the third quarter, expecting to start the test operation in late October 2013. A couple of turbines and generators of 250 kW capacity were manufactured in 2010 and an integrated system of generator and power control module was extensively tested in the laboratory of Korea Electrotechnology Research Institute in 2011. A caisson structure of 15,000 tonnes has been constructed at a test site, which is 1 km off the coastline of Yongsoo in April 2012. An underwater cable between the caisson structure and a power house on land is being deployed and it will be connected to the national grid later.

▲
Construction of Caisson Structure for Yongsoo Wave Power Plant

CHINA

Dengwen Xia
National Ocean Technology Centre

INTRODUCTION

The Chinese Government has paid more attention to marine renewable energy development in recent years. The published "Twelfth Five-Year" Plan of Renewable Energy Development outlines the renewable energy goal till 2015. The Interim Measures for the Administration of Renewable Energy Electricity Price Extra Subsidy promulgated jointly by the Ministry of Finance (MOF), the National Development and Reform Commission (NDRC) and the National Energy Administration (NEA) of the People's Republic of China provides the electricity price extra subsidy for corporations engaged in marine renewable industries to encourage the investment in construction of renewable energy plants. The third round of special funding programme sponsored by the MOF and the State Oceanic Administration (SOA) of the People's Republic of China to implement the RD&Demo of marine renewable energy came into effect in 2012. At the same time, the first round of special funding programme has taken initial effect.

OCEAN ENERGY POLICY

Strategy and National Targets

The Chinese Government published the "Twelfth Five-Year" Plan of Renewable Energy Development (2011-2015) in early August 2012. The overarching target of achieving 20% of electricity generation from renewable sources by 2015 has been proposed. Especially for marine renewable energy, the plan suggests improving the technical level thus to escalate the utilization of marine renewable energy.

Support Initiatives and Market Stimulation Incentives

In March 2012, the MOF, NDRC and NEA jointly drew and promulgated the Interim Measures for the Administration of Renewable Energy Electricity Price Extra Subsidy, which establishes the mechanism of granting extra subsidy to renewable energy programmes.

Main Public Funding Mechanisms

The third round of the special funding programme sponsored by the MOF and SOA to implement the R, D & Demo of marine renewable energy funds new projects in 2012; the total funding is ¥200 million. The three rounds of special funding have led to the distribution of ¥600 million since 2010.

Additionally, the National Key Technology R&D programme, sponsored by the Ministry of Science and Technology (MOST), the Knowledge Innovative Engineering of Chinese Academy of Sciences (CAS) and the National Natural Science Foundation of China (NSFC), supports the utilization and development of marine renewable energy.

Relevant Legislation and Regulation

There are no additional changes in the current Chinese legislation regarding ocean energy, which is defined as the "Renewable Energy Law of the People's Republic of China (Amendment)" implemented from April 2010.

Relevant Documents Released

In March 2012, the Chinese Government approved the National Marine Functional Zoning (2011-2020). China has implemented the marine functional zoning plan since 2002. The new round of National Marine

Functional Zoning (2011-2020) would arrange the sea area utilization and marine environment protection over the next ten years according to the law related to the marine exploitation and protection, such as the Law of SeaArea Use Management (2002) and the Marine Environment Protection Law (2000).

In April 2012, SOA promulgated the National Plan for Islands Protection (2011-2020). As the first islands protection plan, the Plan firstly puts forward making use of marine renewable energy to improve the living circumstance in remote islands.

Related activities

On 1112 April 2012, the 1st Annual China Marine Renewable Energy Conference hosted by the National Ocean Technology Centre (NOTC) and the Administrative Centre for Marine Renewable Energy (ACMRE) was held in Beijing, China. The theme of the conference was "Challenge and Opportunities, the Outlook of the Marine Renewable Energy in China". More than 230 participants from central and local governments, institutes, universities and related corporations discussed and provided suggestions related to the policies, technologies and industries of marine renewable energy.

RESEARCH & DEVELOPMENT

Government Funded R&D

Tidal energy

In August 2012, Jiangxia Tidal Power Plant began the upgrading project sponsored by the third round of special fund programme for MRE. One of the six existing turbines will be improved from 500kW to 700kW to increase 200,000kWh annual power output.

The study on the new-type double-acting tubular turbine is ongoing, which has a 100kW installed capacity. In the design condition, the generating efficiency is 88% when working in a positive direction, and 80% when working in a contrary direction. Now, the turbine is under the prototype test.

Several tidal power pre-feasibility studies are under progress in China, including the 40MW Rushan estuarine tidal power pre-feasibility study in Shandong province, the 20MW Maluan Bay tidal power pre-feasibility study and the 10MW Bachimen tidal power pre-feasibility study in Fujian province.

Tidal current energy

Haineng I tidal current energy device: Harbin Engineering University successfully developed the 300kW vertical-axis tidal current energy device under the support of the National Key Technology R&D Programme. On 19 July 2012, the prototype was deployed in Guishan Channel, Zhejiang province, and has been tested since then. The device carrier is a catamaran-type with dimensions of 24×13.9×2m ,and a the tonnage of 118 ton. There are two 150 kW turbines with start-up velocity of 1.8m/s. The direct current from the device is transported to the island through the underwater cable.

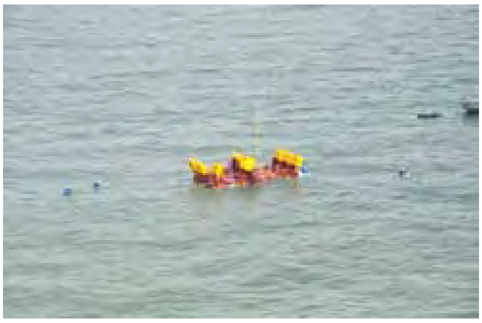
Deployment of the Haineng I tidal current energy

Wave energy

Duck-2 wave energy device: Guangzhou Institute of Energy Conversion (GIEC) of CAS has tested the 10 kW Duck-2 wave energy device in July 2012 and completed the deployment, operation and retrievement successfully. The Duck-2 is now under mending and will be soon deployed for open sea test. Meanwhile, the 100 kW Duck-3 wave energy device and the dedicated deployment vessel has been manufactured. With the help of deployment vessel, it is convenient to deploy the wave energy device.

Duck-2 wave energy device under testing

Pendulum wave energy device: South China University of Technology has successfully developed the 65 kW floating pendulum wave energy device under the support of the first round of special funding programme. In July 2012, the device was deployed for open-sea test and operated for 23 days. Unfortunately, the instruments in the device were destroyed by the lightning strike. The device was repaired after retrieving and will be tested soon.



Pendulum wave energy device under testing

OWC multi-buoy wave power device: Sun Yat-sen University has successfully developed the 10 kW OWC device under the support of the first round of special funding programme. The device is now under preparation tests for more than 6 months.

OTEC

Closed-cycle ocean thermal energy conversion **(OTEC) pilot plant**: the First Institute of Oceanography (FIO), SOA, constructed a 15kW an OTEC pilot plant near a coastal thermal power plant under the support of the National Key Technology R&D Programme and has tested for 5 months. The plant adopts an ammonia-medium turbine for thermal conversion. The system efficiency is 3%. Meanwhile, seawater desalination by the OTEC is also tested.

TECHNOLOGY DEMONSTRATION

Operational Ocean Energy Projects

Jiangxia Tidal Power Plant: the total installed capacity is 3.9MW and the annual electricity generated is 7200MWh. There are in total 6 bulb turbines of 3 types. With the upgrading of one existing turbine from 500kW to 700kW, the total installed capacity will be 4.1 MW before 2014.

Jiangxia Tidal Power Plant has operated well for more than 30 years. The successful operation of the Jiangxia Tidal Power Plant has proven that the construction of tidal power plant would not cause the serious siltation of the cove, nor have a significant environmental impact on local marine ecological environment.

Isolated hybrid power demonstration station in Daguan Island: the demonstration station has been in operation since June 2011 and provided electricity for residents on Daguan Island continuously for 18 months. In addition to the 30 kW wave energy device, 60 kW wind turbines and 10 kW solar cells installed, a 100 kW pendulum wave energy device developed by the NOTC in the support of the National Key Technology R&D programme has been deployed on the island for test and will be added to the station soon.

New Developments

Grid-connected tidal current energy demonstration station in Daishan: constructed by China Energy Conservation and Environmental Protection Group (CECEP), the demonstration station would use the 1MW AR1000™ turbine. CECEP has negotiated with the Atlantis' Singapore HQ for the supply agreement. CECEP will lay a 2.5km underwater cable, the electrical power transmission/distribution system and the grid-connected system in Daishan, Zhejiang province. Now, CECEP has completed the marine engineering investigation.

4.2 / OBSERVER COUNTRIES

NETHERLANDS

Peter Scheijgrond
Tidal Testing Centre

OCEAN ENERGY POLICY

Strategy and National Targets

With the new Government in place late 2012, the target for the contribution of renewable energy to our energy mix has increased from 14 to 16% by 2020. It is expected that most of this target will be realised with biomass, combined heat and power (CHP) and wind energy. The potential for energy from water is about 50-100MW tidal stream energy, 60-100MW tidal barrage and significant potentials for osmotic power and thermal energy from water bodies.

Support Initiatives and Market Stimulation Incentives

The Dutch Government has defined 10 themes, dubbed the top sectors, along which to align research and funding. Two of these are top sector Energy and top sector Water. Projects related to energy from water are support by both these top sectors. Top sector Water looks at local initiatives, governance issues, legislation and regulation by e.g. the Management Authority for Water and Infrastructure Rijkswaterstaat. Top sector Energy focuses more on energy generation, contribution to CO2 goals, financial instruments etc.

Main Public Funding Mechanisms

The main structure to support projects which can contribute to the targets is a feed-in tariff: the Renewable Energy Production Incentive Scheme (SDE+). Only the cheapest forms of sustainable energy qualify for a subsidy. In 2012, there were 5 phases in the application period, between 13 March up to and including 27 December. NL Agency (AgentschapNL) manages the programme. The tender opens for projects that can be realised against 7 cts/kWh. In the 4 subsequent phases, applications are open for incremental steps of 9, 11, 13 and 15 cts/kWh. However, in practice the budget is depleted in the first two rounds, limiting the scheme to the most cost effective and mature solutions. Innovative projects or small projects with a high overhead are unlikely access funds.

Other funding mechanisms available are through several tenders of the Topsectors (usually 25% extra budget on top the total of industrial contributions), NWO for long term university lead research and European Fund for Regional Development.

Relevant Legislation and Regulation

There is no significant legislation or regulation in place for energy from water projects. Projects have to consider a number of relevant permits such as a Water permit from Rijkswaterstaat, a construction permit from the local authority, and environmental permits from the province. Since 2012, a single application can be made for all permits for most projects.

Relevant Documents Released

The Energy from Water Association has published a 10-targets document to support Dutch industry and research activities in the area of energy from water. See www.energieuitwater.nl

RESEARCH & DEVELOPMENT

Government Funded R&D

Only few government funding programmes are active or open at the moment, due to changes in politics.

Dynamic Tidal Power (DTP) Consortium received funding. A consortium of Dutch companies and academic institutions will research the DTP technology with Chinese counterparts. Participating in the Dutch Power Programme are Strukton Engineering, ARCADIS Nederland, Technische Universiteit Delft, Pentair Nijhuis, DNV KEMA, Oranjewoud, IMARES, and H2iD. Their project budget to investigate DTP is €2.1 million, running from 2012 to 2014 and is supported by the Ministry of Economic Affairs.

Participation in Collaborative International Projects

Tidal testing Centre in Den Oever is cooperating in two ERDF projects (on Tidal Arrays and Energy Dams) and the facility is open for access free of charge under the EU FP7 MARINET project.

Bluewater Energy Services are running an EU LIFE+ project on the development of a generic platform for tidal stream turbines. Other partners are Tocardo and Ponte di Archimedes and ERI.

Ecofys was awarded a subsidy of €5,5 million in 2011 under the ERDF programme for the Southern regions to build a 1,5MW tidal demonstration in the Eastern Schelde Storm surge barrier. IHC have now taken over the rights to the Wave Rotor technology and have the intention to complete the project.

TECHNOLOGY DEMONSTRATION

Operational Ocean Energy Projects

Tocardo have been operating a 80kWp direct drive tidal stream turbine in a sluice gate in the Afsluitdijk since 2008.

Tocardo bi-blade turbine in the Afsluitdijk

The **C-Energy** is a 30kWp demonstration project in the Westerschelde near Borssele. The project has been grid-connected since 2009 and operates in the free tidal stream in the river. The project uses the Wave Rotor technology (an omni-directional vertical axis turbine). The project and technology are now owned by the offshore specialist *IHC*.

Wave Rotor technology in the Westerschelde acquired by IHC in 2012

New Developments

Tauw have a license to the Vivace technology developed by *University of Michigan*. Tauw are planning to demonstrate the technology in the river Ijssel near the German border in 2012/2013. VIVACE uses the physical phenomenon of vortex induced vibration in which water current flows around cylinders inducing transverse motion. The energy contained in the movement of the cylinder is then converted into electricity.

Demo unit of Vivace in US

Hydroring BV have built a prototype unit which has been tested in a discharge pipe for several days at the site of Volker Stevin proving the technology works. Hydroring is a ring turbine with a magnetic suspended rotor. The central core of the turbine is open for fish to pass. The Hydroring can be integrated in existing weirs and sluice gates and operates at a small head.

Test rig for the HydroRing at Volker Stevin

RedStack are preparing a small scale osmotic pilot plant at the Afsluitdijk. Permits for a larger, 50kWp plant are already in place. The RED Stack technology uses Reverse ElectroDialysis to generate power from the charge potential between sweet and salt water, by utilizing two kinds of ion exchange membranes.

Oranjewoud are lead partners in the development of a low head tidal site dubbed the Grevelingen Tidal Test Centre (GTTC). The Flakkeese sluice gate located in the Grevelingendam will be used. The complex comprises six tubes and connects the Grevelingmeer (a lake) with the Oosterschelde (a river connected to the North Sea). International technology developers and turbine suppliers are invited to test at this site. The results from the GTTC may offer a solution for a much larger project in the Brouwersdam, where a 60MW tidal barrage scheme is being considered by energy utility Delta and civil engineering company *Strukton*.

Both **IHC** and **Tocardo** have all permits in place to develop free stream tidal projects in the Eastern Scheldt Storm Surge barrier.

FRANCE

Georgina Grenon[1] and Yann Herve De Roeck[2]
[1]Ministère du Développement Durable, [2]France Energies Marines
With thanks to France Energies Marines, ADEME and French Ministry of Ecology, Sustainable Development and Energy.

INTRODUCTION

The development of marine renewable technologies is firmly on France's energy agenda as it strives to diversify its energy profile by developing sustainable long-term industries to bolster energy security. At present, France is reliant on nuclear energy for meeting approximately 75 per cent of its electricity needs. Ocean energy is one of a number of priority sectors identified as being important for France's transition to a low-carbon future.

With extensive tidal and wave resource concentrated on France's north-western coastline and resource opportunities in France's overseas territories, the Government is committed to developing its marine renewables industry. In recent years, France has taken great strides towards coordinating its research and development (R&D) on marine renewable technologies, supporting collaborative initiatives between government and industry. With a strong maritime history, the development of France's ocean energy sector is expected to provide opportunities for diversifying existing expertise and for developing complementary industries. Like for other countries, technology bankability and cost reduction are key priorities for the Government, as well as ensuring that supply chain components required to bring the technologies to commercial fruition are in place. A number of initiatives have been initiated since 2005 with tidal and floating wind projects receiving grants from state and regional agencies. Since 2008, France has focussed attention on a range of initiatives designed to progress ocean technologies towards array configurations. In particular, a call for marine demonstration projects was launched in 2009 by ADEME as part of France's economic stimulus program (Investissements d'Avenir). Among the 5 laureates, two tidal energy projects (Sabella D10 and ORCA) and one wave energy project (S3) had been selected and are currently in progress. The two other laureates are floating wind projects (Winflo and Vertiwind).

The year 2012 saw the confirmation of this trend, with several important actions being kicked off:

- In March, the establishment of the State-backed France Energies Marines (FEM) provided an indication of the Government's commitment to bolstering French competitiveness in the marine renewables industry (see separate section)
- In April, the Ministry in charge of Energy launched a series of studies expected to define the medium and long term strategy for Tidal Energy :
    - A Request for Information was launched by the French Administration on different aspects of tidal technologies
    - RTE (the national transmission grid operator) was commissioned to study the necessary grid connections for tidal energy farms off the Cotentin Peninsula and Brittany coasts
    - The government technical centre of marine expertise was requested to perform a series of analysis and models to better define the exploitable resource under different conditions
- A national consultation on France's energy future was launched in September 2012 with the release of a Roadmap for Energy Transition[1] (*feuille de route pour la transition énergétique*) which outlines the case for embracing low emission sources of energy. Among the priority projects listed in this first roadmap is an initiative (call) for the construction of pre-commercial tidal demonstration projects, due to be announced in early 2013 by ADEME, the Agency for Environment and Energy Management
- In November 2012 the new Government also announced an initiative to develop a strategic plan for marine energy.[2] The results of this study are expected in early 2013
- Announcement of the award of NER300 call, that includes the project for a 26MW floating wind farm off the Mediterranean costs in France (Vertimed)

[1] Ministére de L'Écologie, du Développement durable et de L'Énergie (Ministry of Ecology, Sustainable Development and Energy) Feuille de route pour la transition Ecologique (Roadmap for Ecological Transition), Sep. 2012, http://www.developpement-durable.gouv.fr/IMG/pdf/Feuille_de_Route_pour_la_Transition_Ecologique.pdf.

Cooperation between government, industry and other stakeholders is described as collaborative with several examples of effective cooperation

- A working group was established in 2011 to coordinate efforts on developing marine renewable energy technologies. Quarterly meetings are led by the General Directorate for Energy and Climate Change (DGEC) within the Ministry of Ecology and Energy, as part of the *filière verte* – green industry-initiative.
- Publication of a study on the socio-economic and environmental impacts of ocean energy.[3] The lead on the study was undertaken by DGEC, and involved industry, environmental associations and representatives of other stakeholders

Education and employment aspects are also being reinforced

- Research centres and universities, particularly on the Atlantic coast provide important contributions to developing French expertise. A new generation of marine energy experts are being educated through initiatives such as the specialised Master's programme at ENSTA, a public research and engineering school in Brittany. The programme is being taught in collaboration with industry stakeholders.
- Several initiatives are being piloted by regional agencies, with support of universities and local stakeholders, to address the specific needs of the future job market
- ADEME is also working closely with employment agencies (*Maisons de l'emploi*) to create initiatives for skills development and employment in various green energy sectors (*gestion prévisionnelle des emplois et des competences*). ADEME expects to launch such a project in the field of marine energy in 2013.

Outlook

Despite the need for further technological progress, marine renewables are regarded as an important future source of energy generation in France. In addition to developing its tidal stream and wave resources, France is also focused on developing a competitive advantage in ocean thermal technologies and its overseas territories provide ideal temperature conditions for testing such devices. Small-scale tests are currently being conducted and a pre-commercial scale pilot is being developed in Martinique. ADEME expects that the remainder of the decade up to 2020 will be focused on demonstration projects, pilot farms and the first commercial arrays. Post-2020, ADEME has estimated that marine renewables could account for 0.8% (0.3 Mtoe) of electricity generation in France by 2030.

Creation of France Energies Marines

A significant indicator of the Government's commitment to developing France's marine renewables industry is the establishment in March 2012 of France Energies Marines (FEM). FEM is described as the Institute of Excellence in Carbon-free Energy dedicated to marine renewable energy research, development and innovation. The organisation has an operating budget of €133.3 million over 10 years, derived from both government funds and stakeholder contributions including contributions from private sector entities, research institutes, universities and regional councils. FEM will take a key role in coordinating and conducting R&D on marine renewables.

FEM's objectives

- support competitiveness of the marine renewable energies (MRE) industry : fixed and floating offshore wind, wave and tidal energy and ocean thermal energy conversion
- promote the sustainable nature of MRE technologies and their social acceptability, overseeing France's significant natural potential through its coastal diversity and extent in both metropolitan and overseas territories
- consolidate the level of excellence in MRE research through the synergy of a public-private, through a multidisciplinary structure based on renowned academic and scientific sectors (oceanography, naval engineering, etc.) with lead positions held by industrial firms for key skills (offshore engineering, energy production, etc.).
- ensure the qualification of technologies supported by the industry, sharing means and facilities for simulation, experimentation and especially test sites expected to be operational as of 2013.

Source: http://en.france-energies-marines.org/

[2] Ministére de L'Écologie, du Développement durable et de L'Énergie (Ministry of Ecology, Sustainable Development and Energy), 'Delphine Batho encourages the development of marine energy' 13 December 2012, http://www.developpement-durable.gouv.fr/Delphine-Batho-encourage-le.html

[3] See: www.developpement-durable.gouv.fr/IMG/pdf/120615_etude_version_finale.pdf

05/

DEVELOPMENT OF THE INTERNATIONAL OCEAN ENERGY INDUSTRY: PERFORMANCE IMPROVEMENTS AND COST REDUCTIONS

INVITED PAPERS:

Cost Reduction Pathways for Wave Energy
Mirko Previsic, *Re Vision Consulting*

ESB Ocean Energy Projects – A Utility Perspective on Cost and Performance Requirements
John Fitzgerald and Fergus Sharkey, *ESB Ocean Energy*

UK wave and tidal projects – Update and look ahead
John Callaghan, *The Crown Estate*

From turbine prototype to prototyping an industry: a critical change in perspective
Chris M Campbell and Elisa Obermann, *Marine Renewables Canada*
Tracey Kutney, *CanmetENERGY, Natural Resources Canada*

COST-REDUCTION PATHWAYS FOR WAVE ENERGY

Mirko Previsic[1]
Re Vision Consulting / Sacramento, California

INTRODUCTION

Marine renewable energy, including wave energy, has made continuous progress towards commercialization over the last five years. The impetus behind this evolution in recent years has been the knowledge gained from the deployment of pilot devices, and a focus, more recently, on the deployment of small arrays in Europe. This evolution not only has advanced the commercialization of wave energy technology, it has also provided data that enhance our understanding of the cost drivers and the economics of these projects – data that point to higher commercial opening costs than previously anticipated.

This paper discusses important considerations for evaluating technologies in the wave energy sector, including:

- The projected cost as a function of technology maturity
- Uncertainty ranges in the cost assessment process
- Economies of scale with regard to plant size
- Learning curves
- Technology innovations that can make a significant contribution to long-term cost reductions

Cost Predictions at Different Technology Maturity Levels

The trend of increasing cost predictions observed over the last decade in marine energy is very common in the development of new technologies and new industry sectors. It is typical that during the early phases of product development designers both are optimistic about device performance and have a limited understanding of all the factors that will eventually contribute to lifecycle cost and performance. As a design matures, a more-complete understanding of all aspects of the technology emerges, and cost predictions tend to move higher, as shown in Figure 1. With the deployment of the first commercial machine, the various components of a system's economic viability become fully quantified and understood. This baseline understanding can then be used to develop second-generation technologies, which can be used to reduce cost.

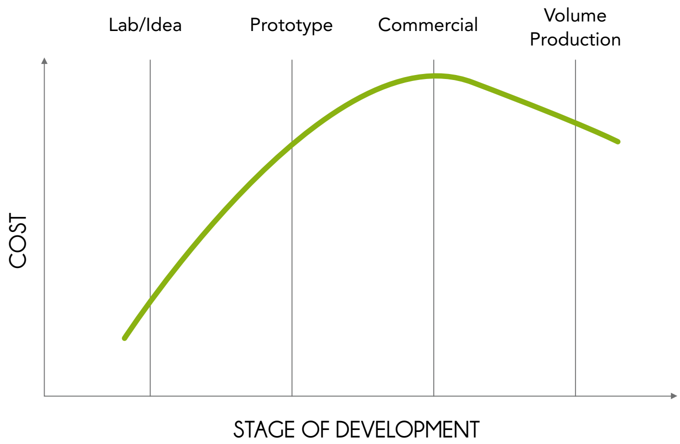


FIGURE 1 : Project cost as a function of development stage.

[1] *Mirko Previsic is the principal at Re Vision Consulting (re-vision.net). Over the past decade, he has focused on accelerating innovation cycles in the marine renewable sector, with a clear focus on economic viability. Contact him at mirko@re-vision.net.*

The key challenge in predicting commercial opening costs in the wave energy sector is acquiring meaningful data. Very few data points are available from actual deployments, and all existing data points come from pilot demonstration projects, not larger-scale farms.

The following section discusses uncertainties inherent in the cost assessment process.

Uncertainties in Cost and Economic Assessments

It is important to understand that most cost assessments carried out to date were based on projected costs and were not derived from direct project experience. The reliance on projected costs leads to uncertainties in the cost assessment process that can be substantial and also that depend on the stage of development of the technology and the assessment detail. Table 1 -- which was developed by the Electric Power Research Institute (EPRI) and adapted by Re Vision Consulting from our experience working with cost estimates from a wide range of power generation technologies -- shows the percent uncertainty as a function of the amount of effort going into the cost assessment and the development status of the technology.

COST ESTIMATE RATING	A MATURE	B COMMERCIAL	C DEMONSTRATION	D PILOT	E CONCEPTUAL (IDEA OR LAB)
A. Actual	0	-	-	-	-
B. Detailed	-5 to +5	-10 to +10	-15 to +20	-	-
C. Preliminary	-10 to +10	-15 to +15	-20 to +20	-25 to +30	-30 to +50
D. Simplified	-15 to +15	-20 to +20	-25 to +30	-30 to +30	-30 to +80
E. Goal	-	-30 to +70	-30 to +80	-30 to +100	-30 to +200

▲
TABLE 1: EPRI cost estimate rating table showing cost uncertainty (%).

The best cost and economic assessment datasets come from demonstration or pilot plants and hence significant uncertainties remain, even if costs are predicted with great care. As shown in Table 1, the range of cost uncertainty for a demonstrated technology is on the order of -15 percent to +20 percent, while the cost uncertainty for a conceptual design has a -30 percent to +200 percent range.

Effects of Plant Size on Cost of Electricity

Wave energy technologies have been deployed in relatively small-scale plants as prototypes or small farms of devices of a few units. The cost of electricity (CoE) from these deployed devices is driven by a combination of factors, including:

- Lack of economies of scale in the manufacturing process
- Need to rely on expensive installation and maintenance methods devised for the offshore industry
- High borrowing cost of capital required to finance these early projects
- Need to overdesign early commercial machines to insure their survival in the harsh marine environment

Most of the above factors driving these high initial costs can be attributed to the lack of any significant deployment scale. Establishing detailed cost breakdowns at different deployment sizes can help to identify the cost-drivers and their importance as technology moves towards commercial scale[2]. (See Figure 2.)

[2] A detailed assessment of the economies of scale in wave energy was carried out under a recently completed independent cost and economic study for the US Department of Energy using inputs from a wide range of device developers. The study, "The Future Potential of Wave Power in the United States," can be downloaded from www.re-vision.net.

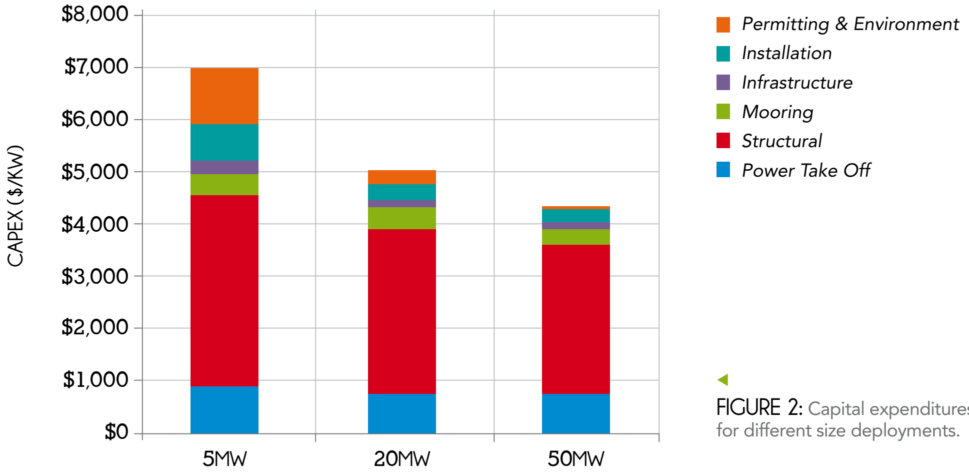


FIGURE 2: Capital expenditures (CAPEXs) for different size deployments.

Significant cost reductions can be observed in the costs that are shared between devices, including permitting and environmental assessment and Infrastructure costs. Cost reductions in these areas are fostered by the ability to share these costs between more devices in a project at a larger deployment scale.

Device-related costs tend to be dominated by steel costs. While cost reductions for manufactured steel are anticipated at large-deployment scale due to the ability to leverage economies of scale in the manufacturing process, these cost reductions are finite. Therefore, further cost-reductions required to make these technologies cost competitive with other sources of energy will require technological innovations and changes, such as:

- Different materials
- Improvements in device performance
- Minimizing load conditions and reducing the structural strength required by load-carrying elements

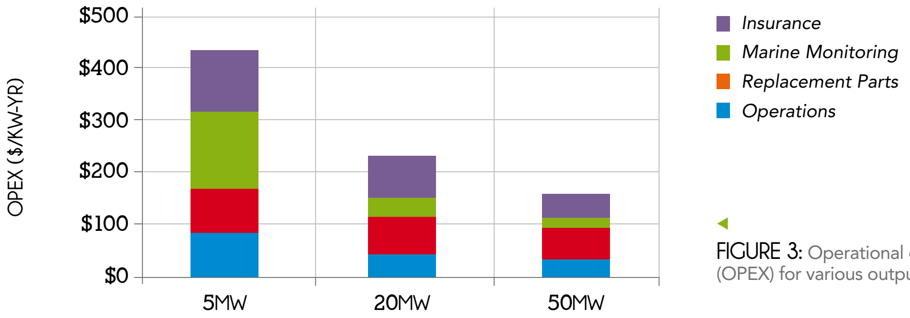


FIGURE 3: Operational expenditures (OPEX) for various output levels.

Even more significant are the cost reductions expected in the operation and maintenance (O&M) of wave energy devices. (See Figure 3) Replacement part costs stay about constant at increasing deployment sizes (no decrease in failure rates is considered), but the other cost centers reduce O&M costs significantly:

- **Insurance costs** - Insuring one-off devices in the offshore industry can be quite costly, on the order of 2 percent of CAPEX per annum. As technology matures and technology-related risks are reduced, insurance costs are expected to drop to a level similar to those for wind energy today.
- **Marine monitoring** - Many early adopter projects are expected to require ongoing monitoring of environmental effects from the plant to satisfy regulatory agencies. This includes active and passive acoustic monitoring, fish studies, and sediment transport studies. These costs do not increase much with increasing project sizes, and hence a net cost-reduction is anticipated.
- **Operational cost** - Cost reductions in this area come largely from being able to switch from carrying out maintenance activities from vessels of opportunity to relying on dedicated vessels that are optimized to carry out the operational tasks of the farm more effectively.

The cumulative effects of moving to larger-scale farms reduce the CoE by approximately 50 percent, without considering any technology innovations, as illustrated in Table 2. CoE in this case was calculated using a fixed charge rate (FCR) of 12.4 percent and a project life of 20 years. This is typical for commercial, mature, utility-scale power projects in the United States. The power-density at the reference deployment location to compute device performance is 34 kW/m.

	PLANT CAPACITY		
	5 MW	20 MW	50 MW
CAPEX	$6,912	$5,035	$4,347
OPEX	$438	$239	$162
O&M percent of CAPEX	6.3%	4.7%	3.7%
PERFORMANCE	5 MW	20 MW	50 MW
Capacity factor	30%	30%	30%
Availability	95%	95%	95%
COE (¢/KWH)	5 MW	20 MW	50 MW
CAPEX Contribution	30	22	19
O&M Contribution	22	12	8
Total	52	34	27

TABLE 2: Reference cost and economic profile from aggregated data and techno-economic modeling

It is important to point out that the CoE in this study was computed using a utility generator CoE model, with returns on capital seen typically in utility-scale power plants, hence the study does not consider the impact on higher capital borrowing costs that are typical for immature technologies. In reality, there would be a risk premium paid by the developer at smaller-scale plants.

Learning Curves

While predicted commercial costs for larger-scale farms are well below present pilot and demonstration cost levels, significant cost reductions will need to be achieved by the industry if the technology is to be deployed at a large deployment scale in competitive utility-industry marketplaces.

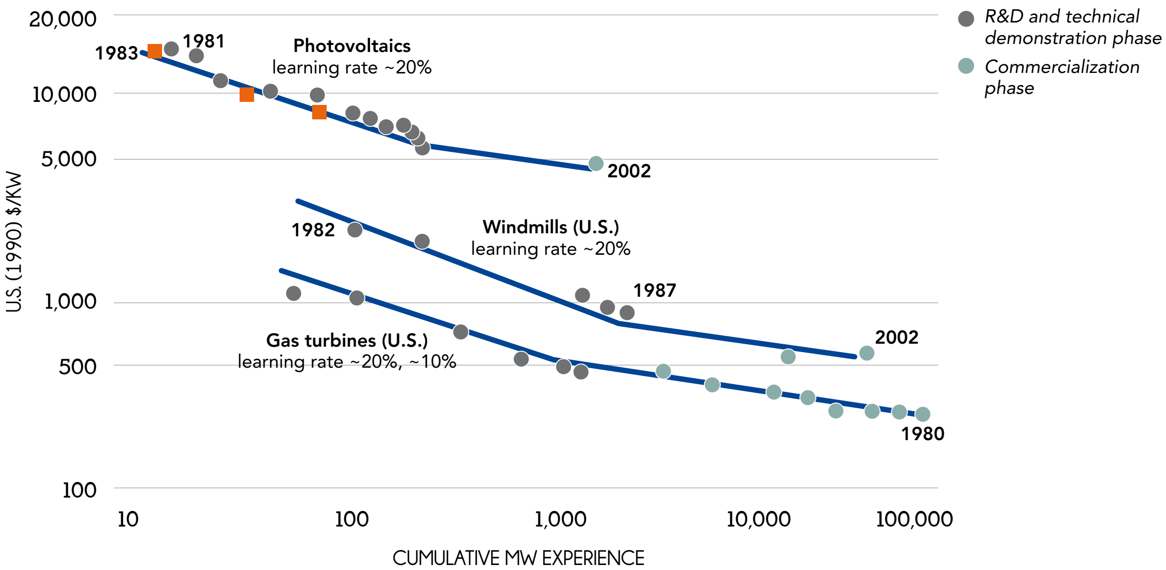


FIGURE 4: Historical learning curves. (Source: "Learning Curves," *Project Finance*, July 2008.)

Learning curves are typically used when predicting longer-term cost reductions for an industry. For each doubling of the deployed capacity, a certain percentage cost reduction is attained. Similar renewable energy technologies have historically attained learning rates on the order of 70–90 percent. Wind technology, for example, which is the most closely related analog, has demonstrated progress ratios on the order of 85 percent. It is important to understand that these cumulative cost reductions are tied to a wide range of factors that can drive cost down, including manufacturing scale, operational efficiencies, improved reliability and availability, and fundamental design changes. (See Figure 4.)

Globally only a limited number of wave energy devices have been deployed, with a cumulative installed capacity of less than 10MW. Furthermore, the wave technology space is characterized by a wide range of different technical approaches, typical for an emerging technology with limited deployments and very similar to wind about 20 years ago. The limited global deployment also means that no technology lock-in has occurred, which is typical for more-established technology sectors. Technology lock-in occurs as a particular technology approach is perfected, manufacturing capacity is built up, and it becomes increasingly more difficult for an alternate technology-topology to enter the market place and compete effectively. A typical example is wind technology, where the 3-bladed, upwind, variable-pitch turbine technology has become the dominant technology. The lack of a technology lock-in makes transformational technology shifts easier to accommodate in the marketplace and opens up the possibility for rapid cost-reduction pathways.

Technology Areas Contributing to CoE Reduction

Within the following set of cost-reduction categories, we used in-house techno-economic models to evaluate how much the CoE from wave energy could be reduced within the near-term, based on the improvement potential of technologies now under development:

Development of efficient operation and maintenance strategies -- Although O&M strategies used in the offshore industry are often adapted for wave energy, they are frequently inefficient and costly. Developing and optimizing O&M strategies and relying on custom vessels specifically built to carry out wave energy operations could allow for a significant reduction in the O&M costs of these devices. Furthermore, recent advances in unmanned vehicle technology (for both surface and underwater vehicles) could allow the use of these vehicles to perform routine inspection and maintenance tasks, a significant opportunity for cost reduction. Early adopter commercial arrays could be used as test-beds for such intervention technologies.

Improving device power capture --The total costs of most wave power machines today are dominated by structural costs. Specifically, these devices show a poor ratio of power output to the structural cost of the absorber. Most of the wave energy devices deployed today are tuned by adjusting the damping on the power takeoff slowly from sea state to sea state. Many of the device concepts studied to date show significant potential to improve power capture if optimal tuning strategies can be applied. To accomplish this improvement, three different areas of technology innovation are needed --

- The ability to accurately predict waves in the open ocean on a time horizon of 30 seconds
- Development of control strategies
- Development of power-conversion systems that allow the implementation of rapid-tuning techniques

Reducing structural overdesign through improved load-prediction tools -- Most design standards used in the offshore industry are very conservative, leading to a tendency of overdesigning the structure. This overdesign is a direct result of the uncertainties in predicting the driving-load cases for which the structures must be designed. An improved understanding of these loads could significantly reduce required safety factors and hence the total material (and cost) of these devices.

Use of alternate materials -- Prototype devices are mostly built from steel today. While steel is a great material choice for building one-off devices and can easily be repaired and modified if needed, it is labor intensive to manufacture and hence expensive. In many cases, composites and concrete could be used instead, providing significant opportunities to reduce labor and material costs in the manufacturing process.

Improve reliability -- The system reliability drives O&M costs because it dictates intervention cycles and also replacement part cost. It is expected that with deployment experience, these system will become more reliable and robust over time.

If the above improvements are applied to the baseline CoE profile of 27 cents/kWh at commercial scale, it would allow a cost reduction on the order of almost 50 percent over present cost to a CoE of about 15.5 cents/kWh, as illustrated in Figure 5. Given the uncertainties in the prediction of the baseline cost of +/- 30 percent, the range of CoE values that could be achieved is on the order of 10 – 20 cents/kWh.

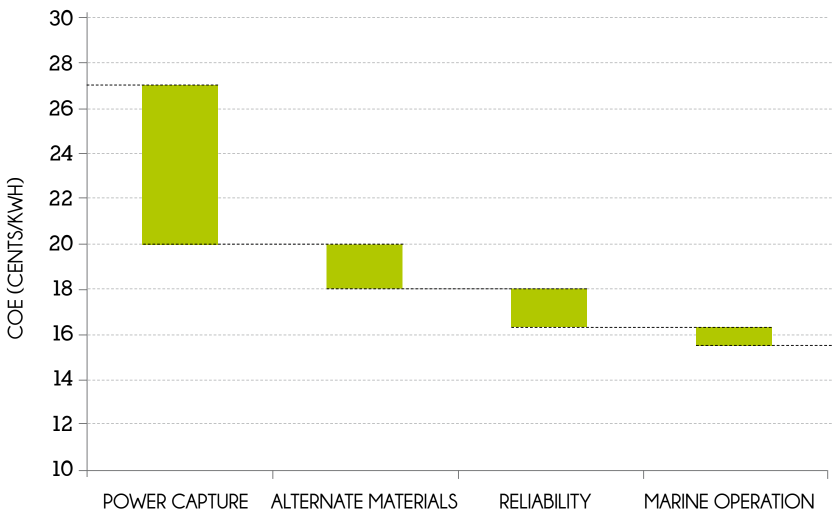


FIGURE 5: Contribution to cost reduction of different cost centers.

Cost Reductions in the US Context

Two scenarios were developed to illustrate how the cost reduction could be established in the US marketplace. The first scenario (the blue lines in Figure 6) shows how the cost would decline from today's levels to the commercial opening cost level predicted by this study if the technologies stayed the same. Cost reductions in this case are largely based on economies of scale (going from 5 MW plants to 50 MW plants) and improvements in device reliability (eliminating the high failure rates typical in pilot and demonstration projects). From the projected opening cost, an 85 percent learning curve indicates predicted cost reductions as the cumulative installed capacity base grows beyond 100 MW. Figure 6 shows that the breakeven target for the lower 48 states, at which no subsidies would be required, occurs at about 50,000 MW cumulative global installed capacity. This point is very similar to the deployed capacity levels at which land-based wind started to become very competitive.

The second scenario (the red line in Figure 6) shows what would happen if an accelerated research, development, and deployment (RD&D) strategy were pursued. Such an accelerated program could potentially reduce the CoE to a level of about 15 ¢/kWh within the first 100 MW of cumulative installed capacity. Cost projections extending out from the 100 MW point were assumed to follow a more traditional learning curve with an 85 percent progress ratio. Figure 6 shows that the CoE would become competitive in Hawaii at a cumulative deployed capacity of less than 200 MW. The learning in this early adopter market would allow costs to be further reduced without any required subsidies, and therefore would minimize the public investment into the technology space. At a cumulative installed capacity of about 3,000 MW, wave power would then reach grid parity with the US mainland (lower 48 states and Alaska).

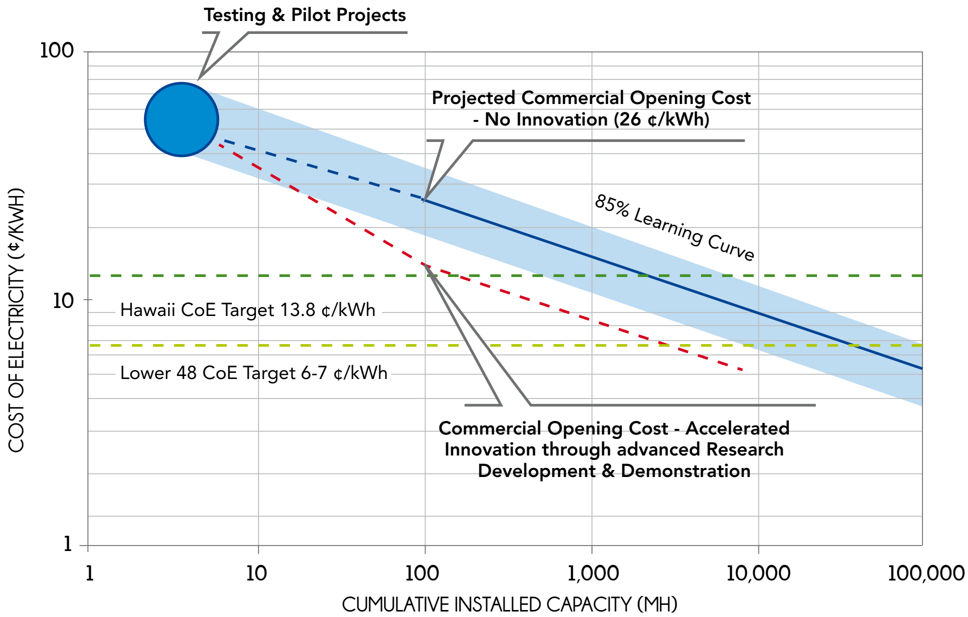


FIGURE 6: Potential cost-reduction pathways

Programmatic R&D Needs

The above areas for innovation can only be attained if strong RD&D programs are in place that nurture this early industry. Although there are no programmatic silver bullets, these guiding principles should be pursued to ensure success:

- **Clear focus on cost-reduction pathways** -- Continued benchmarking of technology innovations with respect to their contributions to reducing the CoE is an important factor in identifying solid cost-reduction pathways and measuring program success. It is important that such benchmarking occurs by modeling commercial-scale arrays from a performance, cost, and economic point of view. Cost drivers at commercial scale are different from the cost drivers at pilot scale, and it is important to engage in the design and optimization process with the end goal in mind.

- **Demonstration and validation** -- Demonstration projects allow the design community to develop a comprehensive understanding of all the elements contributing to the CoE of a particular technology. It is important to transfer the knowledge gained from these demonstrations to the development community so novel design concepts can incorporate those lessons without having to repeat their mistakes. An independent test and validation program can go a long way toward achieving that goal. While this has proven to be difficult to implement, given the commercially sensitive nature of this type of activity, it is a critical ingredient to accelerating technology innovation. Such independent validation work can then be fed back as lessons learned into computational codes and design standards.

- **Development of strong theoretical modeling capabilities** -- The key difference between engineering capabilities existing 30 years ago and today is that modern computing capabilities allow rapid simulation and trade-off studies to be performed on devices that would have required extensive physical testing in the past. Moore's law, which predicted that computational capabilities double every 18 months, has largely held true over the last 30 years (back to when wind power was in its infancy). Over this 30-year period, this yields a millionfold improvement in computational capabilities. By far the most fundamental technological difference today, theoretical modeling allows innovation cycles to be accelerated, enabling rapid progress and reducing cost, by reducing the need for validation and testing. Where traditionally such code development was the domain of national laboratories and universities with supercomputing capabilities, today desktop computers are often sufficient for these problems, enabling small companies to contribute to this code development more rapidly and at much lower cost.

- **Nurturing technological breakthroughs** -- Systematic studies of novel design concepts should be carried out to keep feeding the innovation pipeline. At this stage of wave energy industry development, major breakthroughs are likely to come from radically different design approaches and concepts. Too much focus on established technology could lock out potential breakthroughs that are needed to reduce the CoE in this sector.

Conclusions

The CoE from wave energy devices deployed today is high, primarily because of the lack of any large-scale deployments. However, careful analysis shows that the commercial opening cost of wave energy is just slightly higher than offshore wind, which is at about 22 cents/kWh today in the US. The detailed study of innovation pathways that can lead to a reduction in CoE furthermore shows that significant cost-reduction potential exists, which could reduce the CoE from commercial-scale wave power plants to about 15 cents/kWh in the near future. Nurturing this innovation potential and carefully benchmarking novel concepts and technologies will be critically important over the coming years if substantial cost reductions are to be attained.

ESB OCEAN ENERGY PROJECTS – A UTILITY PERSPECTIVE ON COST AND PERFORMANCE REQUIREMENTS

John Fitzgerald, Technology Manager, ESB Ocean Energy

Fergus Sharkey, Technology Integration Engineer, ESB Ocean Energy

INTRODUCTION

ESB believes Ocean Energy projects can ultimately compete with other forms of renewable energy and that offshore wind economics is a suitable benchmark to inform ocean energy targets. Current offshore wind costs are in the region of €4m/MW installed. ESB sees Ocean Energy cost reducing and performance improving in progressive phases as projects are rolled out by ESB and others. This paper sets out the cost, performance, and revenue requirements for these project phases. While there are areas of significant cost and performance risk in the medium term, technical fundamentals suggest that forms of ocean energy have the potential to meet this cost trajectory and contribute to meeting ESB's renewable energy targets.

The Offshore Renewable Energy Market

In terms of large scale electricity generation market, offshore renewable energy projects must compete with other forms of renewable energy. However, competitiveness must be considered within the context of:
a) Increasing demand for secure and low carbon forms of electricity to meet government targets.
b) Terrestrial constraints to the widespread deployment of onshore wind, hydro and other renewables that are already close to competing with conventional generation.

This has resulted in the introduction of market incentives favouring the importing of renewable electricity from increasingly remote locations back to more densely populated load centres that require it. These incentives are required to overcome the increased costs as well as transmission of electricity over longer distances. Offshore wind is currently the vanguard in this trend and is commercially viable in a number of jurisdictions, including the UK under current incentives of 1.9 Renewable Obligation Certificates (ROCs).

Over 2GW of offshore wind is now operational in the UK alone. There is potential for over 50GW of offshore wind to be further developed under recent seabed leasing rounds in the UK and it is expected to make a strong contribution to meeting UK renewable energy targets, where there are constraints to onshore developments in densely populated areas of southern Britain. As EU energy markets integrate and renewable targets evolve, such offshore wind opportunities offer the potential to meet the demands of more densely populated regions across Northern Europe.

In the medium term, there are no obvious constraints to offshore wind's expansion though there are risks to accessing the deeper water sites identified to meet future requirements. Renewable UK [1] expects investment costs of offshore wind to remain at circa £3m/MW (~€4m/MW)[1] up to 2022 with levelised cost of energy (LCOE) reducing to £130/MWh (€160/MWh) during that period. Given the potential scale of the offshore wind expansion, in order for other forms of offshore renewable energy to gain significant penetration in the market, they will need to achieve similar or lower cost levels. Furthermore, given that ocean energy is operating in a similar or more severe environment than offshore wind and shares similar marine foundation and transmission costs, it is likely that ocean energy will also require economies of scale similar to offshore wind for long term viability. Whereas offshore wind was able to benefit from onshore wind technology to build up such economies of scale, ocean energy technologies must find a similar bridging market to develop a supply chain, while also benefiting from the lessons of offshore wind in terms of electrical infrastructure and marine operations.

ESB and Ocean Energy

ESB (Electricity Supply Board) is the largest utility in Ireland comprising of 6GW of generation capacity in Ireland and Great Britain as well as the transmission and distribution system on the island of Ireland. ESB has ambitious decarbonisation targets requiring significant investment in renewable generation such as wind energy and ocean energy. As such, ESB's interest in ocean energy relates to its considerable potential to contribute to ambitious renewable generation targets.

ESB has a dedicated Ocean Energy team, which is responsible for the strategic approach to developing wave and tidal stream energy generation assets. ESB has had an involvement in Ocean Energy for a number of decades including technology partnership with numerous device developers such as MCT, Wavebob and Wave Dragon. ESB is currently developing their own wave energy project called WestWave (www.westwave.ie) and this has been developed with partners such as Pelamis Wave Power, Aquamarine Wave Power, Ocean Energy Ltd. and Wavebob Ltd. There has been significant progress in technology verification in recent years. However, given that technology is still being proven based on single device testing, ESB envisages that it could still be some time before large commercial ocean energy generation projects of the scale seen in offshore wind energy will become viable investment propositions.

ESB envisages that the bridging market for ocean energy projects will require enhanced public support until economies of scale can be realised. ESB define three broad phases of Ocean Energy projects in this regard. These phases are as follows:

- **Phase 1: Pre-Commercial Arrays (5-10MW)**

This would follow on from successful single prototype device verification. Phase 1 projects would be the first step in establishing the potential reliability and operational costs of ocean energy arrays. As described later, ESB believe that this phase will require significant grant and tariff support. ESB's WestWave project is an example of a Phase 1 project.

- **Phase 2: Small Commercial Arrays (25MW+)**

This Phase would involve the first projects of significant scale using technologies proven with the benefit of Phase 1 projects and expanding manufacturing capability. It is likely that tariff support over and above what would be sustainable in the long term for large scale electricity generation projects may be required to develop projects at this phase.

[1] *An exchange rate of £1 = €1.25 is assumed*

- **Phase 3: Large Commercial Arrays (50MW+)**

This Phase would involve large deployment of technologies in 50MW+ scale arrays. A sustainable tariff must be sufficient to develop projects at this phase, similar to the case of offshore wind. The future availability of a sufficient tariff will depend on the future electricity market and in particular the future supply and demand for low carbon and secure forms of energy.

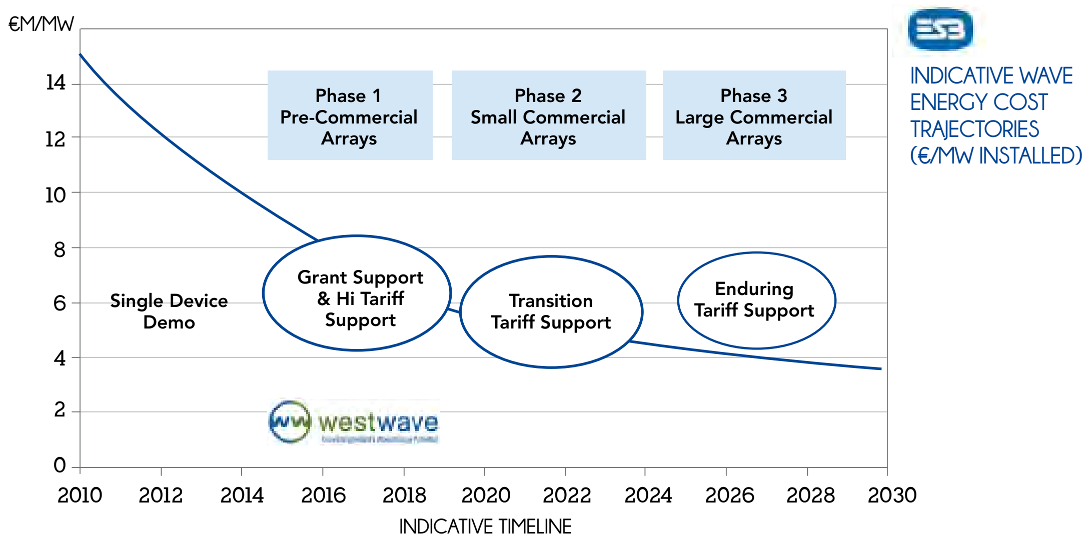


FIGURE 1: An ESB cost projection for projects based on an indicative wave energy technology, showing the role of the WestWave project in putting technology on a commercial cost trajectory

- The WestWave phase 1 project is a 5MW pre-commercial project in Irish waters. Site selection, resource monitoring, grid connection and consenting works are progressing. As part of the first steps in a procurement process for WestWave, ESB has been undertaking detailed technical dialogue with technology developers to support this activity. In undertaking such work, ESB has established Readiness, Cost and Performance criteria to guide suppliers of ocean energy technology towards that required for viable early project investment propositions. ESB present these criteria in terms of:
- Cost & Performance Envelopes
- Technology Readiness Levels (TRLs)

Cost & Performance Envelopes provide clarity on what combination of cost and performance is likely to be affordable from a project investor's perspective. These envelopes will correspond to a particular market. Technology Readiness Levels (TRLs) are used by ESB and others to describe the criteria that technologies must meet for projects at different phases.

Cost and Performance Envelopes

Figure 1 gives an indicative cost trajectory for a typical wave energy technology based on matching offshore wind costs in the future and ESB's estimates of current wave energy cost and performance. However, acceptable capital expenditure (Capex) for such projects will in reality depend on other characteristics of the project, in particular:

- The amount of energy actually produced by the project. This is usually given in terms of capacity factor: the average output as a percentage of the rated capacity installed. This is influenced by reliability and plant uptime as well as variability in the input resource.
- The ongoing annual operational expenditure per MW (Opex), required to operate and maintain the project. This must also include insurance costs.

As such Figure 1 is only an indicative cost trajectory based on particular assumptions of capacity factor and Opex expected for a wave energy technology. To describe acceptable cost constraints more generally, ESB has devised cost and performance envelopes.

Phase 1 Cost & Performance Envelopes:

Phase 1 projects will be required to establish the reliability and predictability of plant cost and performance in advance of larger project investments upon which economies of scale can be built. In order to understand the investment case in such activity, one must consider:

1. The internal rate of return (IRR) demanded by a commercial investor: For such early projects, investors may be willing to accept a reduced IRR where there is strategic value to being involved in an early project, especially where it would provide access to subsequent investment opportunities. An IRR of 7% is selected for this analysis to determine realistic phase 1 project financing costs, though this will vary depending on the project and the investor appetite. An IRR of 7% is probably optimistic as it is not risk-adjusted to the uncertainty involved in the deployment of hardware in the marine environment without a proven track record of reliability. However, it is assumed that all safety critical risks can be managed satisfactorily at this stage.

2. The revenue stream for the project: ESB considers that tariffs of circa €300/MWh are expected to be available in some jurisdictions (e.g. 5 ROCs in the UK market) to undertake these early projects of limited scale.

3. The lifetime of the project: ESB considers that a reduced project economic life of 10-12 years is appropriate for Phase 1 projects as early technology is likely to become obsolete and be replaced at a date earlier than the design life.

Based on the above, an affordable Capex per MW can be established. In order to represent technology variability, the affordable investment cost is presented in Table 1(a) and is calculated for varying capacity factor and annual Opex (as a percentage of Capex). Table 1(a) is the case where it is assumed that no additional grant aid is available for the project. This table provides an "affordable cost envelope" for private project financing of early stage projects.

The influence of capacity factor and Opex on these affordable costs is considerable. For example, for a tidal stream generation plant rated at 1MW, a Capex in excess of €7m is affordable where capacity factors of 45% can be achieved but this reduces to only €4.75m where capacity factors are limited to 30% (for the case of Opex is 4% of Capex). Similar variation is apparent for wave energy technology, where there is ambiguity about how such converters are rated and consequently about what capacity factors can be expected. This highlights the need for caution in how developers rate energy conversion machines and for how investors compare the cost of technology using the crude metric of €/MW installed. There will also be variability in terms of Opex depending on reliability, accessibility and the cost of maintenance operations, such that the affordable investment costs can also vary considerably depending on these attributes. This highlights the need for project investors to undertake detailed technical due diligence to establish realistic expectations of energy production, reliability, availability and operational costs.

Affordable Capex falls within the range of €3-8m for the range of capacity factors and Opex considered in Table 1(a). ESB anticipates that such early projects are more likely to fall in the range of €6-10m per MW. As such, it is likely there will be a shortfall between the required €6-10m and what can be justified as a commercial investment alone, especially where Opex is likely to be high and reliability low for phase 1 projects. As such, these projects are termed "pre-commercial" by ESB and require additional sources of funding.

Additional Phase 1 project funding:

Grant aid is likely to be essential to establishing this vital bridging market of phase 1 ocean energy projects. Funding supports are already available through schemes such as the EU's NER300 and the UK's Marine

Energy Array Demonstration Fund (MEAD). Table 1(b) below repeats the calculation for phase 1 projects, but considers the case where a €3m/MW grant is made available to the project. Note that this grant aid is further limited to half of the total investment cost up to a maximum of €3m (as in many cases it is difficult to grant fund projects by over 50%). The resulting project costs that can be funded in this way then fall into the Capex range of €6-10m and ESB consider these as acceptable project costs for phase 1. As such, the cost and performance envelope described in Table 1(b) represents a useful target to maximise the chance of successfully financing a phase 1 project.

Phase 2 Cost and Performance Envelopes:

Once phase 1 projects are performing reliably and operational costs and associated risks are understood with some confidence, it should be possible to build a business case for larger projects and take advantage of economies of scale. Grants will be difficult to justify at this scale and so such projects will need to be commercial based on a bridging tariff alone (such as the 5 ROC market in the UK or equivalent feed in tariffs). Phase 2 affordable costs are calculated here based on:

1. The internal rate of return (IRR) demanded by an investor: Projects at this scale will need to pay for themselves using normal commercial finance. An IRR of 10% is selected for this analysis, though this will depend on the project and the investor. However, offshore projects will carry risk, and some contingency must be included to attract such finance.

2. The revenue stream for the project: ESB considers that tariffs of between €220/MWh (proposed Renewable Energy Feed in Tariff (REFiT) for Ireland) and €300/MWh (approx equivalent to 5 ROCs in the UK market) will be available to undertake these early projects of limited scale. There may also be niche applications for technology (e.g. island communities or in applications for offshore oil and gas activities) where higher tariffs are payable for small projects. €300/MWh is used in this analysis.

3. The lifetime of the project: A project life of 20 years (approaching expected design life of hardware) is appropriate for Phase 2 projects.

Table 2 shows the resulting affordable cost and performance envelope for phase 2 projects. An enhanced tariff of €300/MWh is likely to be unsustainable at scale and therefore there will be a limited market for such projects.

Phase 3 Cost and Performance Envelopes:

Economies of scale, incremental technology improvements as well as improvements in performance and reliability will have a significant impact on the economic case. In order to achieve economic parity with offshore wind, ESB considers the following case:

1. The internal rate of return (IRR) demanded by an investor: As for Phase 2 projects, an IRR of 10% is selected for this analysis. Offshore projects of large scale will still carry risk, and some contingency must be included to attract such finance.

2. The revenue stream for the project: Based on Renewable UK [1] projections for offshore wind levelised costs; ESB considers that tariffs of £130/MWh (~€160/MWh) may be available for offshore renewable generation projects beyond 2020.

3. The lifetime of the project: A project life of 25 years is considered appropriate for Phase 3 projects.

Table 3 represents the resultant cost and performance envelope. Note that the current investment cost of offshore wind projects in the UK are circa €4m/MW and such projects can now achieve a capacity factor of 35-40% with operational costs of €80-90k/MW/year (see Renewable UK [1]). These costs are within the envelope described in Table 3 (highlighted). As such, Table 3 represents the cost and performance currently required for a significant market to develop, as for offshore wind.

a)

PHASE 1: AFFORDABLE INVESTMENT COSTS FOR GENERATION PROJECTS						
OPEX €m/MW/annum CAPEX €m/MW			ANNUAL OPEX AS % OF CAPEX			
			2.0%	4.0%	6.0%	8.0%
CAPACITY FACTOR	20%	*OPEX*	*0.07*	*0.13*	*0.17*	*0.20*
		CAPEX	3.60	3.17	2.83	2.55
	25%	*OPEX*	*0.09*	*0.16*	*0.21*	*0.26*
		CAPEX	4.50	3.96	3.53	3.19
	30%	*OPEX*	*0.11*	*0.19*	*0.25*	*0.31*
		CAPEX	5.40	4.75	4.24	3.83
	35%	*OPEX*	*0.13*	*0.22*	*0.30*	*0.36*
		CAPEX	6.30	5.54	4.95	4.47
	40%	*OPEX*	*0.14*	*0.25*	*0.34*	*0.41*
		CAPEX	7.21	6.34	5.65	5.11
	45%	*OPEX*	*0.16*	*0.29*	*0.38*	*0.46*
		CAPEX	8.11	7.13	6.36	5.74
to yield a 7% IRR for a 12 year project life where a tariff of €300.00/MWh is payable						

b)

used in table 7

PHASE 1: AFFORDABLE INVESTMENT COSTS INCLUDING A GRANT FACILITY						
OPEX €m/MW/annum CAPEX €m/MW			ANNUAL OPEX AS % OF CAPEX			
			2.0%	4.0%	6.0%	8.0%
CAPACITY FACTOR	20%	*OPEX*	*0.12*	*0.20*	*0.26*	*0.29*
		CAPEX	6.19	5.11	4.27	3.68
	25%	*OPEX*	*0.14*	*0.25*	*0.32*	*0.37*
		CAPEX	7.09	6.24	5.34	4.60
	30%	*OPEX*	*0.16*	*0.28*	*0.38*	*0.44*
		CAPEX	7.99	7.03	6.27	5.52
	35%	*OPEX*	*0.18*	*0.31*	*0.42*	*0.50*
		CAPEX	8.89	7.82	6.98	6.30
	40%	*OPEX*	*0.20*	*0.34*	*0.46*	*0.56*
		CAPEX	9.79	8.61	7.69	6.94
	45%	*OPEX*	*0.21*	*0.38*	*0.50*	*0.61*
		CAPEX	10.69	9.41	8.39	7.58
to yield a 7% IRR for a 12 year project life where a tariff of €300.00/MWh is payable **and a grant of €3m/MW is available up to matched funding level**						

TABLE 1: Phase 1 project affordable investment costs without grant (a) and with matched funding grant up to a maximum of €3m/MW (b)

used in table 7

PHASE 2: AFFORDABLE INVESTMENT COSTS FOR GENERATION PROJECTS						
OPEX €m/MW/annum CAPEX €m/MW			ANNUAL OPEX AS % OF CAPEX			
			2.0%	4.0%	6.0%	8.0%
CAPACITY FACTOR	20%	*OPEX*	*0.08*	*0.13*	*0.18*	*0.21*
		CAPEX	3.82	3.34	2.96	2.66
	25%	*OPEX*	*0.10*	*0.17*	*0.22*	*0.27*
		CAPEX	4.78	4.17	3.70	3.33
	30%	*OPEX*	*0.11*	*0.20*	*0.27*	*0.32*
		CAPEX	5.74	5.01	4.44	3.99
	35%	*OPEX*	*0.13*	*0.23*	*0.31*	*0.37*
		CAPEX	6.69	5.84	5.18	4.66
	40%	*OPEX*	*0.15*	*0.27*	*0.36*	*0.43*
		CAPEX	7.65	6.68	5.92	5.32
	45%	*OPEX*	*0.17*	*0.30*	*0.40*	*0.48*
		CAPEX	8.60	7.51	6.66	5.99
to yield a 10% IRR for a 20 year project life where a tariff of €300.00/MWh is payable						

TABLE 2: Phase 2 Affordable capital investment for commercial projects >25MW

PHASE 3: AFFORDABLE INVESTMENT COSTS FOR GENERATION PROJECTS						
OPEX €m/MW/annum CAPEX €m/MW			ANNUAL OPEX AS % OF CAPEX			
			2.0%	4.0%	6.0%	8.0%
CAPACITY FACTOR	20%	OPEX	0.04	0.07	0.10	0.12
		CAPEX	2.15	1.87	1.65	1.47
	25%	OPEX	0.05	0.09	0.12	0.15
		CAPEX	2.69	2.33	2.06	1.84
	30%	OPEX	0.06	0.11	0.15	0.16
		CAPEX	3.23	2.80	2.47	2.21
	35%	OPEX	0.08	0.13	0.17	0.21
		CAPEX	3.77	3.27	2.88	2.58
	40%	OPEX	0.09	0.15	0.20	0.24
		CAPEX	4.31	3.73	3.29	2.95
	45%	OPEX	0.10	0.17	0.22	0.27
		CAPEX	4.85	4.20	3.71	3.32
to yield a 10% IRR for a 25 year project life where a tariff of €160.00/MWh is payable						

used in table 7

current offshore wind (approx)

TABLE 3: Phase 3 Affordable capital investment for commercial projects >50MW to be competitive with offshore wind.

Technology Readiness Levels (TRL)

In order for a project to demonstrate that it can fall within an acceptable cost envelope, technology developers must complete a test and validation programme that demonstrates this to the satisfaction of investors. ESB has developed technology readiness level (TRL) definitions [2], adapted from those developed for aerospace technology by NASA. The ESB wave energy TRL definitions have gained some broader acceptance as a means to evaluate the maturity of ocean energy conversion technology and to communicate validation requirements for future projects. ESB's TRL levels range from TRL1 to TRL9 with TRL9 being a fully developed 'commercial', certified product with significant in-service experience (similar in maturity to offshore wind converters such as the ubiquitous Siemens SWT 3.6-120 turbine). Under the ESB definition, the TRL level of a technology is evaluated based on it meeting certain criteria in both functional readiness and lifecycle readiness.

- *Functional readiness* describes how it has been verified that a technology performs its specified major functions including energy production performance and maintaining station.
- *Lifecycle readiness* describes how well it has been verified that the lifecycle of a project based on the technology is viable, considering aspects such as manufacturability, deployability, operability, reliability, maintainability and overall commercial viability.

The TRL levels are summarised in Table 4 below.

TRL	FUNCTIONAL READINESS	LIFECYCLE READINESS
1	Basic principles observed and reported	Potential uses of technology identified
2	Technology concept formulated.	Market and purpose of technology identified
3	Analytical and experimental critical function and/or characteristic proof-of-concept.	Initial capital cost and power production estimates / targets established
4	Technology component and/or basic technology subsystem validation in a **laboratory environment**. (>1:25 Froude)	Preliminary Lifecycle design: targets for manufacturable, deployable, operable and maintainable technology
5	Technology component and/or basic technology subsystem validation in a **relevant environment**. (>1:15 Froude)	Supply-chain Mobilisation: Procurement of subsystem design, installation feasibility studies, cost estimations, etc.
6	Technology **system** prototype demonstration in a **relevant environment**. (>1:4 Froude)	Customer interaction: consider customer requirements to inform type design. Inform customer of likely project site constraints.
7	Technology **system** prototype demonstration in an **operational environment**. (>1:2 Froude)	Ocean Operational Readiness: management of ocean scale risks, marine operations, etc.
8	Actual Product (first of type) completed and qualified through test and demonstration. (1:1 Froude)	Actual Marine Operations completed and qualified through test and demonstration.
9	Operational performance and reliability demonstrated for an array of type machines.	Fully de-risked business plan for utility scale deployment of arrays

TABLE 4: TRL summary definition. Full definition in [2]

Although the ESB TRLs also make reference to the cost and performance of a technology within the lifecycle readiness criteria, this is in an absolute sense relative to a particular project business case. Using the cost and performance envelopes outlined above, it is possible to consider economic viability in terms of target costs. These define the maturity of a technology in terms of economic competitiveness in more detail. Table 5 proposes economic competitiveness levels for offshore renewable technology.

LEVEL	ECONOMIC COMPETITIVENESS	RELEVANT ESB COST TARGETS
1	Potential for incremental changes to meet key performance requirements to enable commercial projects	Table 1(b)
2	Economic viability under distinctive and favourable market and operational conditions. **Limited market**	Table 2
3	Sufficiently competitive to be a "new entrant" renewable energy of scale in general electricity generation market (e.g. offshore wind). Tariff Supports Required. **Significant market**	Table 3
4	Sufficiently competitive to be best cost renewable (e.g. onshore wind). Supports may still be required. **Very large market potential**	N/A
5	Competitive in general electricity market without special support mechanisms. **Market constrained by resource only**	N/A

TABLE 5: Economic Competitive Level summary definition.

Weber [3] also recently published similar Technology Performance Levels (TPLs) as well as the concept of using both TRLs and TPLs to plan and describe the progression of technology development. Such definitions of economic competitiveness permit technology developers to consider aspects such as:

- Although a technology may be very well advanced in terms of prototype testing, even to full scale, it may have poor performance and high costs. While it may be viable for pre-commercial projects under particular financial incentives, it may not be on a trajectory towards overall competitiveness in the renewable energy market.
- Experimental iterations to increase economic performance at a high readiness level may be cost prohibitive as any design changes require repetition of large scale prototype testing. However, achieving high economic performance at a low readiness level may also be difficult due to the limitations of laboratory and numerical analysis and in such cases important deficiencies in technology may not be detected until it is tested at larger scale in the ocean. By considering a combination of TRLs and economic targets, Weber [3] describes how one can capture an optimal "trajectory" in terms of developing technology towards the performance and readiness required by utility project developers.

In the economic competitiveness levels described in Table 5, Level 3 is a realistic ambition for offshore renewables as it defines generation technology that is cost competitive with "best new entrant" forms of renewable energy, required to meet government targets (currently offshore wind in the GB market). However, there is inherent uncertainty on the future value of renewable electricity and this relates to the demand derived from government targets as well as the potential future availability of newer, more competitive forms of renewable energy. For now, ESB considers offshore wind to be the appropriate "new entrant" renewable energy that ocean energy must match economically in order to access a market of scale in Great Britain and Ireland electricity markets. As such, the cost and performance envelope defined in Table 3 is indicative of an ESB Phase 3 project cost requirements.

Project Requirements

ESB have set required TRL and economic hurdles for each of the three project phases outlined previously, as shown below in Table 6. This shows the developing combined technical maturity (TRL) and economic viability which must be demonstrated before each phase of projects can be developed.

ESB OCEAN PROJECT	INDICATIVE PROJECT	REQUIRED TRL LEVEL	REQUIRED COST ENVELOPE
Phase 1 Project	Pre-Commercial Array (5-10MW)	TRL 8	Table 1(b)
Phase 2 Project	Small Commercial Array (25MW+)	TRL 9	Table 2
Phase 3 Project	Large Scale Array (50MW+)	TRL 9	Table 3

TABLE 6: TRL and Economic Requirements for ESB Ocean Energy Projects

Ocean Energy Cost Trajectories

Based on the cost envelopes in Tables 1 to 3, it is possible to extract realistic cost trajectories that ocean energy must achieve for commercial acceptability. For example, consider a wave energy technology that has been verified to TRL8 and is assessed to have a potential capacity factor of 25% (based on the application of specifications such as IEC 62600-100 and 62600-101 as well a realistic allowance for availability). Assuming that investors are happy that annual operational expenditure (Opex) can be kept at or below €250k per MW per year then the affordable capital expenditure (Capex) according to table 1(b) is €6.24m/MW. If this is sufficient to fund a phase 1 project, then as the industry grows for subsequent projects there is potential for overall project Capex and Opex to fall while energy yields increase. Table 7 below sets out a realistic trajectory for wave energy technology costs through the three phases. In this case, ultimate project Capex is projected to be €3.3m/MW, a little less than offshore wind, though Opex is a little higher, perhaps owing to accessibility to high wave energy sites. Figure 1 is based on this same logic, though it should be considered that different technologies will have varying expectations of capacity factor and Opex so many such Capex curves could be produced. It is only important that Capex, Opex and capacity factor are collectively within acceptable envelopes (Tables 1 to 3) at each stage.

PROJECT PHASE	PROJECTED CAPACITY FACTOR	PROJECTED OPEX	TARGET CAPEX
1 5-10MW	**25%** based on TRL8 testing and application of IEC standards and allowance for poor reliability initially.	**€250k/MW/year** based on allowance for poor reliability, increased need for intervention and lack of dedicated supply chain / vessels	**€6.2m/MW** (from table 1b)
2 25MW+	**30%** based on phase 1 project performance and demonstrated reliability (TRL9)	**€200k/MW/yr** based on improved reliability and supply chain experience	**€5.0m/MW** (from table 2)
3 50MW+	**35%** based on improved reliability, design and access to more energetic sites.	**€130k/MW/yr** based on bespoke supply chain facilities, vessels and much reduced need for repair intervention.	**€3.3m/MW** (from table 3)

TABLE 7: Realistic Cost Projections for Wave Energy Conversion Projects

Project Cost Breakdown

The costs given above are total project costs and it is useful to consider what cost breakdown is expected for wave and tidal energy projects. These costs can be broken down in various ways [4], [5] but will be broken down here under the below headings. Offshore wind is a useful guide [6] to understand the typical breakdown that is targeted. Opex is not considered here, so this is a breakdown of Capex only.

- **Development** – This is typically 4% of total Capex for offshore wind, it is expected that this will be similar for wave and tidal farms with similar consenting requirements.
- **Converters** – WECs / TECs – In offshore wind, turbines are typically 40% of the total Capex, uninstalled. It is expected that this will be closer to 45-50% for both wave and tidal farms due to the potential for savings in other Capex components.

- **Foundations / Moorings** – In offshore wind, foundations make up approximately 20% of the total Capex, uninstalled. This is likely to be similar for tidal farms, with fixed foundation requirements, but potentially less for wave farms, with mooring system requirements.
- **Electrical Connection** – In offshore wind, electrical components make up 15% of the total Capex, uninstalled. This is expected to be similar for wave farms, due to similar distances from shore, but perhaps less for tidal farms, which can be close to shore.
- **Installation** – In offshore wind, the installation of foundations, electrical cables and turbines makes up approximately 20-25% of the total Capex. This is expected to be similar for tidal farms but perhaps less for wave farms depending on WEC installation strategy.

There is still a large variety of wave and tidal energy converter concepts, more so in wave energy. It is therefore difficult to put a fixed breakdown of Capex for both that will be universally accurate. A prospective breakdown of costs for wave and tidal energy arrays is Shown in Figure 2. These cost breakdowns are for Phase 3 projects only. Phase 1 and 2 projects are expected to have a different cost breakdown.

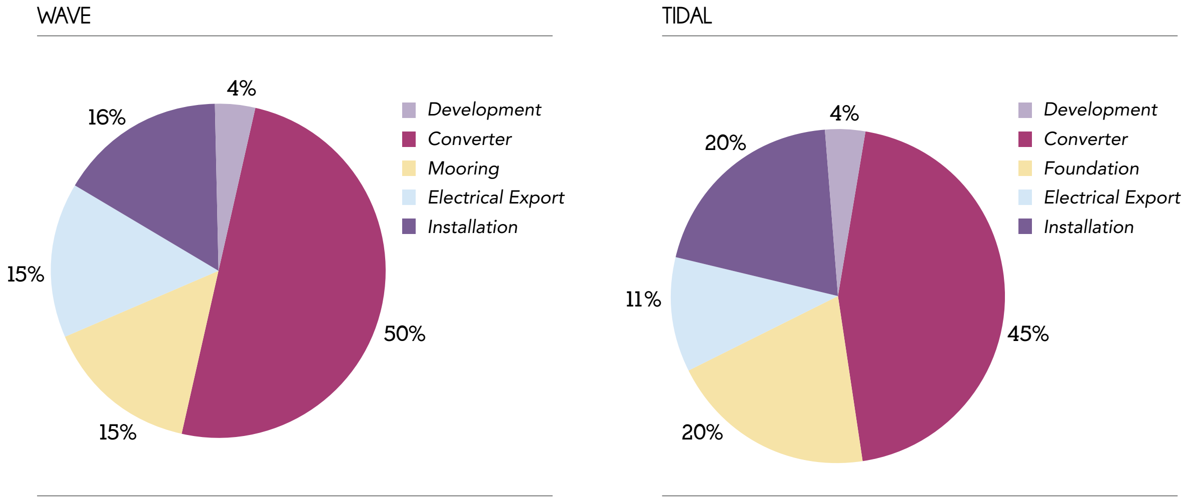


FIGURE 2: Prospective Capex Breakdown for Phase 3 Wave and Tidal farms

Although the target costs for Ocean energy projects are circa €4m/MW to be comparable to offshore wind (Table 3), this would equate to a target costs of circa €2m/MW for the wave energy converters and €1.8m/MW for tidal energy converters themselves. This is the 'dry' cost to deliver the hardware to the quayside before installation. It is possible to assess metrics, such as structural tonnes/MW of particular solutions to see if the material costs are likely to be consistent with these long-term requirements. Cost requirements are similar to the current cost/MW of offshore wind energy converters. Given that the input energy resource for both wave and tidal energy can be denser than for wind energy (see Table 8), ESB see no fundamental reason why these alternative offshore energy converters cannot achieve competitive structural costs. However, in order to realise this, technology developers must ensure that their solutions have the potential to be as structurally efficient as offshore wind energy converters in order to meet the longer term phase 3 cost requirements.

Cost Indicators and Risks

Presently, evaluating the economic potential for technology can prove difficult as only a small number of wave and tidal technology developers have progressed past TRL7, at which stage there is credible visibility of final commercial costs. In terms of performance there are only a small number of technology developers that have completed meaningful levels of generation and running hours and can therefore give credible capacity factor projections. As such, the evaluation of economic competitiveness at this stage is, for the

RENEWABLE POWER SOURCE	POWER DENSITY
Wind Power per m² of input wind at 12m/s (typical rated velocity of an offshore wind turbine)	1,100 W
Tidal Power per m² of input water current at 2.4m/s (typical rated velocity of a tidal turbine to achieve >30% capacity factors)	7,000 W
Wave Energy flux per m² of seastate Hs = 6m, T_z = 8s sea state (typical rated sea state for wave energy converters to achieve >30% capacity factors)	9,400 W (average in upper 10m of sea)

TABLE 8: Power Flux from different renewable sources of power through a vertical 1m² reference area. Reference wind velocity, current velocity and sea state are chosen as typical rated values that would be sufficient to achieve capacity factors of >30% at suitable sites.

most part, more subjective than that of TRLs. ESB believe that technology developers will have a firmer understanding of costs and performance once TRL8 is achieved. In the meantime, there are other cost indicators which may be used to inform economic competitiveness. These 'cost indicators' at a pre TRL7 phase include:

- Tons of steel per MW
- Wetted surface area and working surface area (e.g. blade area, rotor swept area, and float size)
- Foundation or mooring concept
- Mechanical complexity of overall system and PTO
- MW rating for single unit
- Type of WEC and PTO
- Construction, installation, and maintenance concepts

Other than the basic costs of the converter hardware itself there are other cost risks to projects which are outlined briefly below. If the focus is solely on reducing the cost of wave or tidal energy converters, design changes could introduce other non-core cost risks to a project. These risks include;

- **Device rating** – Most wave and tidal energy converters are currently rated at around 1MW. By increasing the MW rating of devices, there can be a significant reduction in other parts of the Capex such as electrical infrastructure, installation and foundations/moorings, consistent with the experience of offshore wind. Also increasing the unit rating may reduce the Capex per MW of the converter itself, although this has remained relatively constant for offshore wind.
- **Capacity factor** – The capacity factor has a direct impact on the productivity per MW installed and this is reflected clearly in acceptable cost and performance envelopes (Tables 1-3). However, the electrical system must also be rated for the maximum output power and a lower capacity factor means a low utilisation of this expensive infrastructure. Low capacity factors can result in significantly increased downstream per MW infrastructure costs. In wind energy, optimal capacity factors are higher than for onshore wind as a result of the cost of offshore electrical balance of plant (35-40% offshore as opposed to 25-30% onshore).
- **Insurance** – Insurance is a critical part of the viability of a project and it is likely that in early stage wave and tidal farms this will contribute significantly to Opex. In-service data, certification, and warrantees will go some way towards reducing the insurance costs and managing the safety critical risks to the satisfaction of utility investors.

Conclusions and Perspective

The above assessment shows a challenging but realistic view of the market for ocean energy. In some jurisdictions the market conditions exist to allow investment in pre-commercial Phase 1 small array projects. These projects will begin the process along the cost reduction trajectory presented. Supplementing offshore wind with wave or tidal stream energy as large scale sources of renewable generation will only occur when costs are competitive. ESB believe that ocean energy can develop towards sustainable and competitive projects. This trajectory is achievable, based on economies of scale and learning rates, but consistent supports and long term policy are required to deliver a bridging market to cost competitive ocean energy. Technology developers that focus on delivering technology within realistic economic constraints are likely to be successful in the long term.

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"FROM TURBINE PROTOTYPE TO PROTOTYPING AN INDUSTRY: A CRITICAL CHANGE IN PERSPECTIVE"

Chris M Campbell and Elisa Obermann – Marine Renewables Canada
Tracey Kutney – CanmetENERGY, Natural Resources Canada

Over the course of 2012, there have been signals that the global marine renewable energy industry focus has evolved from a technology commercialization paradigm to a focus on demonstrating a clean power industry option. This shift has been recognized by both Canada and the UK, as the immediate goal sought by both countries has become demonstration of multiple devices – "arrays" - to create utility-scale power plants.

Prototyping an Industry

The focus on array-scale development is evident in many of the recent Canadian and UK initiatives. With both countries viewed as global leaders in this industry, it is very telling of where the sector is going and what is needed to achieve a sustainable industry.

Canada's strategy to date has been focused on the end-game and the steps to demonstrate a marine power industry solution, with an assumption that technology would advance to meet its needs. The 2011 Canadian Marine Renewable Energy Technology Roadmap[1] focused primarily on solving the challenges of transitioning from the technology development phase to the array or power plant phase—and highlighted the technical and business opportunities this transition would present. A central tenet of the roadmap strategy was that a broader suite of innovation must be launched urgently, effectively and efficiently. The roadmap identifies pioneer prototype power plants as the incubators for this critical transition.

Even as the first single device deployments were still only planning initiatives, Nova Scotia's Fundy Ocean Research Center for Energy (FORCE) made a commitment to develop the offshore interconnectors for four pilot tidal power plants – arrays of devices with capacity outputs of 16 MW each, totaling 64 MW. This action was based on the idea that the demonstration needed to convince the power industry and its financiers was not simply that a tidal generator can produce significant amounts of electricity, but the critical step was going to be showing the availability and reliability of electricity generated from a marine power plant.

That same perspective is seen in the UK's most recent strategic support initiatives. The Marine Energy Array Demonstrator scheme overtly targets two such pilots – at least three devices and preferably in the 5-10MW capacity range[2]. The Marine Renewables Commercialization fund is focused on levering two or more such projects ahead in Scotland, to prove:

[1] *http://www.marinerenewables.ca/technology-roadmap/*

"That wave and tidal devices can be installed in various real-sea locations.
That installation vessels and teams can install and commission multiple devices in close proximity.
That the supply-chain for marine energy devices and balance of plant can be mobilized to manufacture and assemble multiple components, beginning to deliver economies of scale.
That power from such devices can be combined and delivered to shore.
That devices can generate continuously to the grid, and that projects can be funded based on the sale of that electricity."[3]

The focus on driving these developments with market-pull mechanisms has become increasingly critical, with a number of mechanisms advancing in several countries. In the UK, the Renewable Obligation Certificate (ROC) banding sets a premium on the value of wave or tidal energy and after a number of reviews, the UK Department of Energy and Climate Change has decided to offer 5 ROCs per MWh.[4] This premium of about $300 over the clean electricity price is designed to support projects up to 30 MW - a scale proposed to encourage commercial-scale pilots. In the United States, the first tidal power purchase agreement for Ocean Renewable Power Corporation (ORPC) was created by an obligation to purchase tidal power.
Similarly, Canada has also recognized the need for this market support. In Nova Scotia, the Community Feed-In-Tariff (COMFIT) of $652/MWh has attracted five community-scale project proposals from Fundy Tidal Inc. which have received approval by provincial government. Nova Scotia is also in the process of setting an array-scale FIT which is expected to be established in spring 2013.

Accelerating the innovation

The focus on array-scale development partly stems from the need to accelerate innovation around some of the leading generator systems. For example, the Canadian roadmap recognized this relationship between larger projects and innovation stating: *"Canada's marine renewable energy sector must continue to develop in this direction to accelerate innovation and collaboration, and drive the development of commercial- scale wave, in-stream tidal, and river-current demonstrations."*
The roadmap proposed that the development of technology incubators to share experience and accelerate innovation is fundamental to the progress along these pathways. It suggested that aggregating early activity will create the scale and momentum needed to incent the development of technologies and the transfer of skills from other sectors (such as oil and gas, fisheries, marine and salvage operations). The early achievement of full-scale demonstration would showcase Canada's engineering, procurement and construction capabilities as a demonstration of expertise by solving the needs of these projects.
Likewise, the pursuit of full-scale demonstration is evident in UK thinking. The 2012 Technology Innovation Needs Assessment by UK's Low Carbon Innovation Coordination Group identified initial deployment of first arrays and R&D to address the challenges identified in the first arrays[5] as two priority actions. The 2010 UK UKERC/ETI roadmap also focused on crosscutting enablers for cost reduction to accelerate progress on the first arrays[6]. Similarly the UK Technology Strategy Board and Scottish Government recently committed funding to seven projects focused on array development enabling technologies addressing the range from designs for installation and service vessels to a standard foundation connection.[7]
Building a supply chain, which assembles the best component supply, manufacturing and operational approaches, is a problem for one-off assemblies and demonstrations. Array-scale development catalyzes this industrial-scale activity because they create needs that demonstrations of single devices can avoid... The multi-device systems will require an integration of technology, technical approaches and operating practices, which may not have been needed for single-device testing. The requirements of these prototype power plants are already driving the focus of strategic and collaborative innovation initiatives (Figure 1).

[2] *http://www.decc.gov.uk/en/content/cms/meeting_energy/wave_tidal/funding/mead/mead.aspx*
[3] *http://www.carbontrust.com/client-services/technology/innovation/marine-renewables-commercialisation-fund*
[4] *http://www.decc.gov.uk/assets/decc/11/consultation/ro-banding/5936-renewables-obligation-consultation-the-government.pdf*
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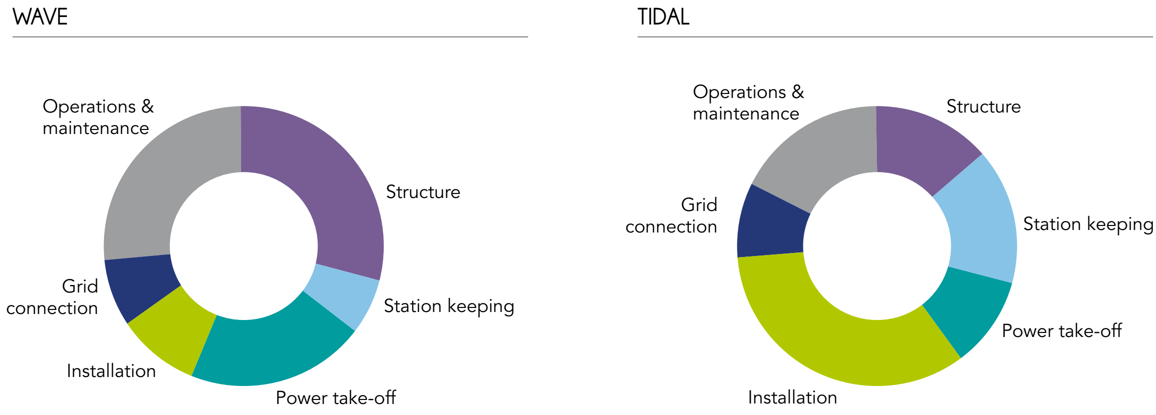


FIGURE 1: Cost Components for Wave and Tidal Energy Projects (source: Carbon Trust)

Refining real costs, avoiding delays caused by not being a favoured-customer and having to make one-off decisions on installation and operations can mean that the learning from device trials may not actually contribute to an understanding of the necessary industrial approaches. The breakdown of the cost components indicate that generator structures are only part of the total cost of the power plant.

Team building for industrial scale delivery

Multi-device projects will require the human and financial resources that will resemble those required in the 'developed' industry. Financing and delivering the first array projects present challenges that are beyond the capacity of the device developers who out of necessity have been playing project development roles for their early device testing and demonstration. The need to engage in site characterization, permitting and all of the other "project" development activities has meant that device developers have had to incorporate skills that draw on financial resources, yet may not be part of the long-term business plan. In some cases and at some stages the "burn rate" associated with this non-core business has exceeded that for the core device development.

Delivery of these projects is a new challenge and the 2012 launch of Nautimus (Vattenfall, Abengoa and Babcock) is a significant development triggered by the needs of the first projects.
This evolution will push technology developers to move into the business of manufacturing series of devices for these projects – the engagement of major integrator/manufacturers (Alstom, Andritz, DCNS, Lockheed Martin, Siemens, Voith Hydro and others) over the last year or two are bringing that transition into focus.
These array projects will enable electricity companies like Emera, EDF, E.ON, RWE, Scottish Power, SSE, Vattenfall and others to understand the scope and opportunity that future development presents. The electricity industry is accustomed to power projects in the hundreds of MW or even gigawatt scale and typically sees high transaction costs, interconnection challenges and attrition rates when dealing with large numbers of smaller projects. Reliability and availability risks are perceived to be higher when managing small projects. Against this background it is not surprising that utilities want to see arrays of devices in order to build confidence in the generation method and to have operations that at least are indicative of a small operating power plant.

Finance is a continuing challenge as projects require the amount of capital normally addressed by project finance, but without the experience expected by the project finance players. Narec Capital is advancing an effort to manage risk and mobilize finance[8]. Morgan Stanley has been attracted to the sector through the UK's Meygen array project. Strategic financiers like the European Investment Bank are seeing the opportunity to make these early industrial-scale projects the learning experience that financiers need.

[8] *www.nareccapital.com*

After A Decade Of Technology Push

Many lessons that can be applied to these future projects have been learned from what has essentially been a push to commercialize marine renewable energy generation devices. The multi-year operation of Siemens/MCT SeaGen in Strangford Lough, Northern Ireland, has not only demonstrated technical feasibility but, more generally, the concept of a megawatt-scale marine renewable energy generator that can be installed and operated for long periods. As 2012 closes, at least two wave technologies, and three other tidal generator companies have accumulated experience with these large–scale generators.

The scale of prototype trials, the time to iterate technological developments and demands for accessing marine sites have been challenges addressed by the creation of permitted test centres with shared infrastructure. Despite this support, development rates have been slower than anticipated, in large measure due to financing difficulties which has also made supply chain development challenging.

Potential tidal and wave converter customers or investors, now familiar with the "accepted" design of wind turbines, express concern that the wide range of device designs demonstrate an immaturity in the marine renewable energy industry. This raises concerns about how to pick a winner. Most customers need to see the integrated system that makes the device into a power plant they could use. These customers want to know: does it reliably supply electricity? Are the project risks understood? Is the electricity affordable? Is this a viable hedge against long-term cost-of-fuel increases?

The interests of the integrator/manufacturers

Some of the early device demonstration successes have attracted strategic partners with a background in manufacturing, system integration and sales in the power market. In a few cases, these early device demonstrations have led to partnerships with utilities. These relationships extend from access to components, access to design, testing or development experience, all the way to outright ownership by the manufacturers or utilities.

In most cases manufacturers have had a real interest in moving to a stage where orders for series-production units can be expected. In some cases manufacturers are deciding to focus on the core of the devices, as closest to their existing industry experience, believing that other parts of the single device "system" needs to be significantly developed by others with better experience and capacity.

Emergence of a market pull

Climate change action agendas have resulted in progressive targets for renewables development. In some countries a drive for energy security has added to this an imperative for resource diversity. In others it has been a focus on new marine industrial and economic opportunity that drove initial investment in technology development and more recently the transition to create economic value out of the delivery of complete clean marine electricity solutions.

These market-pull initiatives have resulted in ratepayers investing in the success of pilot projects – the rate is only paid for what the project delivers. As experience drives down cost, these market support mechanisms are expected to adjust so that ratepayer support for later projects can be decreased ultimately to the point where marine renewable energy promotes will compete equally with other renewables. With the energy densities of marine resources and ongoing reductions of lifecycle costs, these projects may ultimately be competitive with traditional forms of energy generation.

Market pull is likely to stimulate formation of supply chains that will work together through all stages, eventually delivering the scale at which marine renewable energy is that competitive choice.

The issue is now one of demonstrating integrated systems: how projects are sited and permitted; how they are designed and installed, how they are operated and maintained, what their availability as a "plant" is and how the power output meets power interconnection requirements.

For marine electricity

The focus is shifting toward demonstration of reliable and scalable projects that can deliver marine electricity of value to the consumer. It must be demonstrated, even through these initial trials, that it will be practical for a significant part of the power portfolio to come from marine renewable energy. More importantly, the potential for improvements in operations and costs must be demonstrated to make the case for marine renewable energy as a reliable and competitive electricity resource.

What must marine renewable energy demonstrate?

It was suggested earlier that there are significant parts of an industrial-scale project that may not be addressed in device–level demonstrations. This includes some of the following aspects:

Technical solutions:

Balance of Plant

The functionality of devices may have been demonstrated, but plans for utility-scale installations and their servicing can be expected to drive the development of new approaches to: foundations, installation and service vessels, cable interconnection and a host of other technical and operational interfaces that integrate those generation systems into a commercial plant.

Generation systems

For marine renewable energy plants to be accepted market solutions, they must demonstrate that they can meet utility interconnection requirements. While a system may be blind to a small demonstration, experience with pilots large enough to attract system administrator interest is critical. System control and data delivery needs to meet utility industry standards. Resource forecasting, plant availability and energy forecasts have to be suitable as planning and operating tools.

Balance of Project

The scale change from device trials to prototype arrays will require new responses from regulators, supply chain, manufacturers and financiers. It is critical that this prototype value chain be demonstrated if the scalability of marine energy is to be pursued.

CAPEX acceptability

System capital costs have to reduce by almost 2/3 to compete wind.[9] This reduction in CAPEX has to be achieved by incorporation of new innovations in project design and development, learnings from doing that eliminate costs, and economies of scale that come from series production of components and from maximizing deployments from project infrastructure. This trend will only be driven by a focus on the needs of multi-device projects.

OPEX viability

Operations and maintenance expenditures also have to be reduced by almost 2/3. Significant improvements will come through integrations of operations and maintenance planning into equipment selection or design, availability of service infrastructure that matches project needs for planned and emergency service and through development of operating experience and the efficiencies that that will bring. Only with larger-scale deployments will the necessity to refine operations and maintenance come to a head.

Conclusion

While there is certainly a lot of room for proving and improving of marine renewable energy technologies, it is clear that focusing on prototyping an industrial approach will drive those improvements and the emergence of a host of enabling technologies and operational approaches. The necessary technology transfer, supply chain development, customer engagement, access to the financial sector and political support depends on that demonstration of what this industry will look like and what it can offer.

[9] *www.lowcarboninnovation.co.uk/document.php?*

UK WAVE AND TIDAL PROJECTS – UPDATE AND LOOK AHEAD

John Callaghan

Programme Manager (Wave & Tidal), The Crown Estate

INTRODUCTION

During the last decade, commercial interest in wave energy and tidal energy grew significantly in the UK, supported by government policy measures which encouraged research, development, testing and demonstration of generation technologies. In the current decade, interest is continuing to grow, particularly towards making the transition from proving the viability of technologies, currently deployed as single prototypes, to constructing and operating initial projects involving multiple machines deployed in arrays. The Crown Estate is pleased to be playing a key role in this, primarily by providing leases for seabed sites. As owner of the offshore seabed around the UK within territorial waters (up to 12 nautical miles from the coast) and with rights to provide licences in the Renewable Energy Zone (further offshore, in some places up to 200 nautical miles), we are landlord to the majority of UK wave and tidal projects. But our work in wave and tidal energy extends beyond this. We have a strategic long-term interest in growth of the industry, which means we are interested not just in leasing sites today but actively supporting their development as projects over years to come, including such steps as obtaining statutory consents and securing grid connections. We are also now considering investing in first array projects in order to help catalyse investments by others.

This article gives an overview of recent developments in the UK, considering government policies which support project development and the industry's progress in developing projects; summarises The Crown Estate's activities over the last few years; and briefly looks ahead to the future, including opportunities for international engagement and collaboration.

Policy and regulatory context

Government bodies across the UK, including the central government and devolved administrations of Scotland, Wales and Northern Ireland, support the development of wave and tidal energy. The 2010 Coalition Agreement indicated that the UK Government would "introduce measures to encourage marine energy" and the devolved administrations have made similar commitments.

Waters around the UK are now subject to Strategic Environmental Assessments (SEAs) for wave and tidal energy development. In connection with a European Commission Directive concerning the 'assessment of the effects of certain plans and programmes on the environment', SEAs provide recommendations for plan implementation and are used to inform guidance for developers. The first country of the UK to complete a SEA for wave and tidal energy was Scotland, with the assessment covering waters to the north and west of the country (2007)[1]. Subsequently, wave and tidal development in waters around England and Wales was covered in an offshore energy SEA by the UK Department of Energy and Climate Change, DECC (2011)[2]; and a SEA for offshore wind, wave and tidal development in multiple zones off Northern Ireland was completed by the Northern Ireland Department of Enterprise, Trade and Investment (also 2011)[3].

There will soon be a consistent level of revenue support for wave and tidal stream projects across the UK. This is under the Renewables Obligation, a supplier obligation system involving green certificates known as Renewables Obligation Certificates (ROCs). Various renewable electricity technologies are eligible for different numbers of ROCs per unit of generation. Wave and tidal stream generating stations are becoming eligible for 5 ROCs per MWh for projects up to 30 MW capacity. The ROC price varies, but at the current

[1] See http://www.scotland.gov.uk/Topics/marine/marineenergy/wave/WaveTidalSEA

[2] See http://www.offshore-sea.org.uk/consultations/Offshore_Energy_SEA_2/index.php

[3] See http://www.offshorenergyni.co.uk/

level of approximately £40/MWh[4], this support is worth £200/MWh[5] (about US $320/MWh[6]) on top of the wholesale price of electricity. The move to 5 ROCs/MWh follows the 2011 Renewables Obligation Banding Review and the level is set to take effect from April 2013.

DECC is currently developing a new revenue support system as part of a package of measures called Electricity Market Reform (EMR). The new system will be based on Contracts for Difference Feed-in Tariffs, which work by reference to a fixed 'strike price' for each technology and a variable 'reference price' reflective of the wholesale electricity price. At times when the reference price is below the strike price, the generating company will receive a subsidy equal to the difference between the prices, and vice versa (the company will have to pay the difference when the reference price is above the strike price). This arrangement is intended to ensure that the generating company always receives the strike price but not more than this. Initially, strike prices will be set by an administrative process, but over time, the Government intends to move to an auction system. Contracts for Difference will be available from 2014 (except in Northern Ireland, where they will be offered from 2016) and the Renewables Obligation is planned to be phased out in 2017. In the transition period, generating companies will be able to choose between revenue support under the Renewables Obligation or Contracts for Difference[7].

In addition to revenue support, DECC and the Scottish Government are offering capital grants for first array projects in two parallel initiatives called the Marine Energy Array Demonstrator scheme (MEAD, £20m, US $31.7m) and the Marine Renewables Commercialisation Fund (MRCF, £18m, US $28.6m). The Scottish Government is also offering to invest in first arrays through its Renewable Energy Investment Fund (REIF, £103m, US $163.4).

UK projects may also benefit from European support. In December 2012, it was announced that two UK tidal projects had been offered funding through the European Commission NER 300 programme. These are ScottishPower Renewables' Sound of Islay project (€20.7m, US $27.5) and Siemens Marine Current Turbines' Kyle Rhea scheme (€18.4m, US $24.4m)[8].

Progress in project development

As of January 2013, there are 41 wave and tidal projects under development or operation in UK waters on The Crown Estate, with a total potential installed capacity of over 2.0 GW. The projects are of four main types:

- Managed test and demonstration facilities, which provide infrastructure and/or services for several single prototypes and small arrays of devices;
- Test projects up to 3 MW, which typically involve a single prototype technology;
- Test and demonstration projects between 3 MW and 50 MW, which are generally for arrays of devices; and
- Commercial array projects of 50 MW or greater capacity.

Table 1 gives the number and total potential capacity of each type and Figure 2 shows the geographic locations of the projects.

TYPE OF SITE	NUMBER OF SITES	TOTAL POTENTIAL INSTALLED CAPACITY [MW]
Managed test and demonstration facilities	7	See note*
Test projects up to 3 MW capacity	9	< 10
Test and demonstration projects, 3 MW to 50 MW capacity	12	> 190
Commercial projects, 50 MW+ capacity	13	1,800
Total	41	Over 2,000

TABLE 1: Types of UK wave and tidal site on The Crown Estate, January 2013. *Some test and demonstration facilities are not grid-connected. Of those that are, the project capacity is variable depending on the technologies installed.

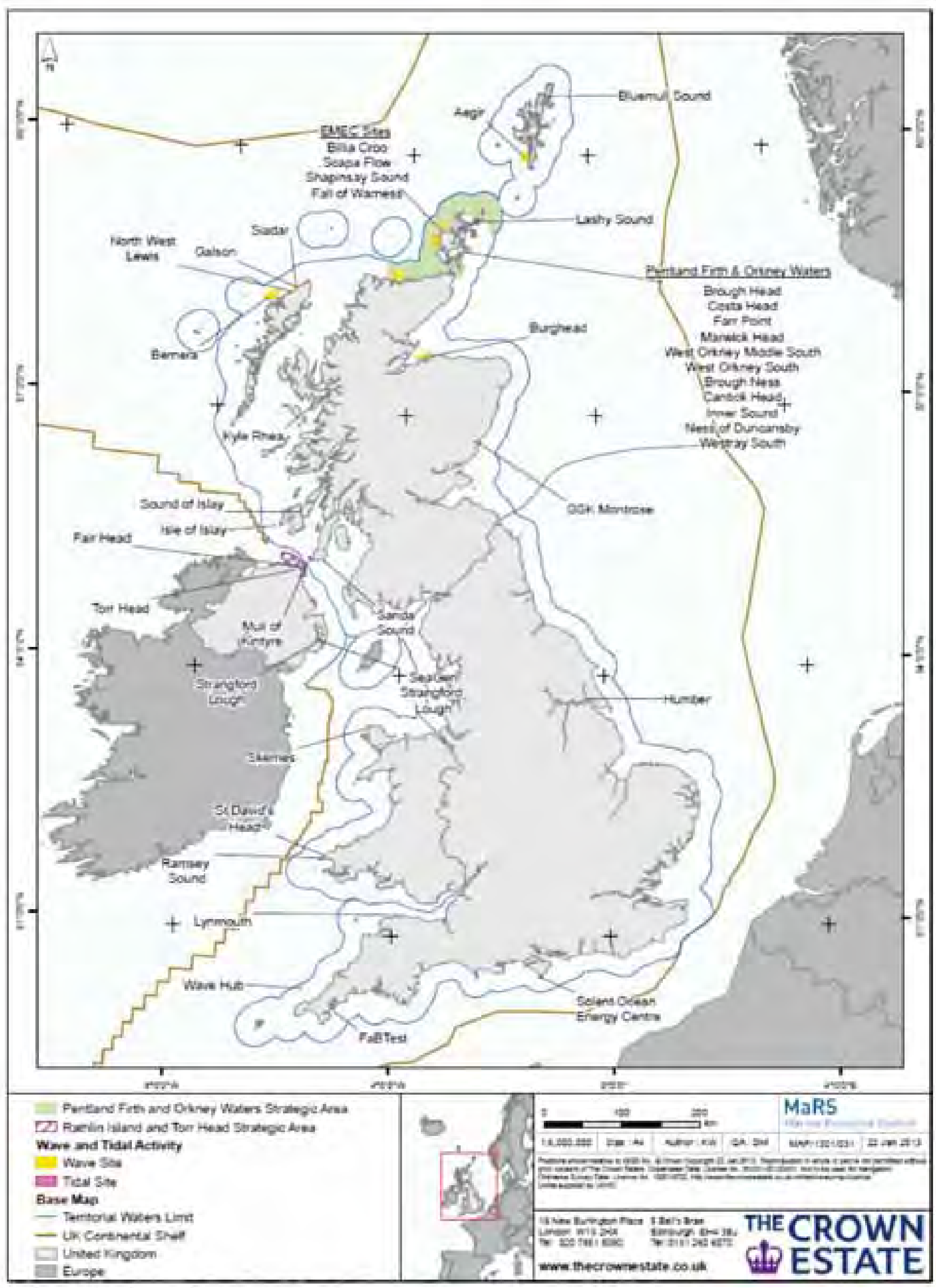
[4] *Source: Non-Fossil Purchasing Agency, www.e-roc.co.uk*

[5] *Not including the recycling benefit. For further information about the Renewables Obligation, see the Department of Energy and Climate Change website: http://www.decc.gov.uk/en/content/cms/meeting_energy/renewable_ener/renew_obs/renew_obs.aspx*

[6] *Exchange rates correct as of January 2013.*

[7] *For further details on EMR, see the Department of Energy and Climate Change website, http://www.decc.gov.uk/en/content/cms/meeting_energy/markets/electricity/electricity.aspx*

[8] *Source: European Commission; see http://ec.europa.eu/clima/news/articles/news_2012121801_en.htm*



▲
FIGURE 1: Locations of UK wave and tidal site on The Crown Estate, January 2013

The managed test facilities include three sites for sea trials, where devices may be tested but not grid-connected. These are the European Marine Energy Centre (EMEC) Fall of Warness site; the EMEC Shapinsay Sound site (Orkney); and Fabtest, a facility operated by Falmouth Harbour Commissioners in Falmouth Bay (Cornwall). The other four sites are either already grid-connected or planned to be connected and include the EMEC Billia Croo and Scapa Flow test areas (Orkney); Wave Hub near Hayle (Cornwall); and the Solent Ocean Energy Centre (SOEC) off the Isle of Wight. EMEC has been operational since 2004 and seen a number of technologies deployed at its sites, including, for instance, the Pelamis Wave Power wave energy converter, two of which were deployed during 2012[9]. Wave Hub was installed during 2010 and Fabtest opened in 2012. The SOEC is currently under development.

[9] *Source: EMEC. For further details about EMEC's recent activity, see http://www.emec.org.uk/blog-another-record-year-for-emec/*

Of the test projects up to 3 MW, which are in various places around the UK, one is currently operating: Siemens Marine Current Turbine's Seagen machine at Strangford Lough (County Down). The other projects are currently under development, including scoping and preparation of environmental impact assessments (EIAs) to support consents applications. The same is generally true of the test and demonstration projects between 3 MW and 50 MW, except ScottishPower's 10 MW Sound of Islay tidal project, which received consents from the Scottish Government (Marine Scotland) in March 2011. Several other projects are awaiting consents decisions from either the Scottish Government (including Aquamarine Power's 10 MW Galson and 30 MW North West Lewis projects) or Welsh Government (including Siemens Marine Current Turbines' 10 MW Anglesey Skerries scheme).

The commercial projects of 50 MW+ are in two main areas: the Pentland Firth and Orkney waters strategic area around the north of Scotland and the Rathlin Island and Torr Head strategic area off Northern Ireland. In total they comprise approximately 90% (1,800 MW) of the total potential installed capacity of current UK wave and tidal projects. The Pentland Firth and Orkney waters projects have been under development since 2010, including environmental scoping and EIA preparation. In July 2012, Meygen submitted a consents application for its Inner Sound project to the Scottish Government. Following connection applications from several of the Pentland Firth and Orkney waters developers, new grid infrastructure to enable wave and tidal projects to be connected to the west of Orkney Mainland, and the power to be transmitted back to the Scottish mainland, is being designed by transmission company Scottish Hydro Electrical Transmission (SHE Transmission, part of SSE). Development of the Rathlin Island and Torr Head projects is getting underway, following The Crown Estate awarding agreements for lease in October 2012.

The Crown Estate's work to date

The Crown Estate's strategic objective in wave and tidal energy is to support growth of the emerging industry, attract significant investment to the sector and encourage major players to commit to development. We are also helping government bodies to define policies that support development of the industry.

We have been providing seabed rights for wave and tidal projects for over ten years, starting with initial prototype projects such as the IT Power (later to become Marine Current Turbines) Seaflow installation off Lynmouth, Devon. However, the wave and tidal portfolio has shown particular growth since 2008, due to the Pentland Firth and Orkney waters leasing round between 2008 and 2010, the Rathlin Island and Torr Head leasing round from 2011 to 2012, and leasing of demonstration and small commercial projects over the encompassing period – including via four six-month applications windows between autumn 2010 and autumn 2012. During 2012, we ran an industry engagement exercise to invite views on where, when and how we should lease further wave and tidal sites. We are currently reviewing the responses and updating our leasing approach, with a further announcement planned in due course.

In 2009, we announced plans to support development of the Pentland Firth and Orkney waters projects and subsequently established an enabling actions fund of £5.7m (US $9.0m). This is covering a range of research, data gathering and other activities to de-risk development of the projects, across various topics including environmental impact assessment, physical characterisation of sites and supply chain development. Examples to date include a study to identify cumulative environmental impacts, near-shore bathymetry surveys and a report on the products and services necessary to build the projects. The work is selected and monitored by The Crown Estate and a Developers Forum, which comprises representatives of the Pentland Firth and Orkney waters developers. Some of the work is done in partnership with other organisations, including the Scottish Government and agencies (e.g. Marine Scotland and Highlands and Islands Enterprise). A number of reports are free to download from our website[10].

Looking ahead

The range of sites we have leased in UK waters reflects the diversity of activities underway here. Technology developers and manufacturers are continuing to focus on testing devices to make them ready for commercial deployment, while project developers are preparing sites to receive the devices in future years.

[10] *See http://www.thecrownestate.co.uk/energy/wave-and-tidal/pentland-firth-and-orkney-waters/enabling-actions/*

It is appropriate these activities are happening in parallel given that the project development process can take several years to receipt of consents and new grid infrastructure is sometimes needed.

The next key milestone for the industry is installation and operation of first array projects. In the next few years, it is possible that several first wave and tidal arrays could be constructed and installed around the UK, by technology manufacturers and project developers working together. Such projects will improve technical understanding about how multiple devices can best be installed in particular site conditions and clarify operational performance characteristics (e.g. wake effects) and costs.

There are opportunities for international engagement in reaching this next milestone. While wishing the UK to maintain its international lead, The Crown Estate is highly supportive of such engagement. In the last year we have been pleased to respond to information requests from organisations in a number of countries, including the USA and Canada. We are also developing a data and information sharing system for the wave and tidal industry, known as the Knowledge Network, which will have international reach.

For more about The Crown Estate's work in wave and tidal energy, please contact us as follows:
waveandtidal@thecrownestate.co.uk
www.thecrownestate.co.uk/energy/wave-and-tidal/

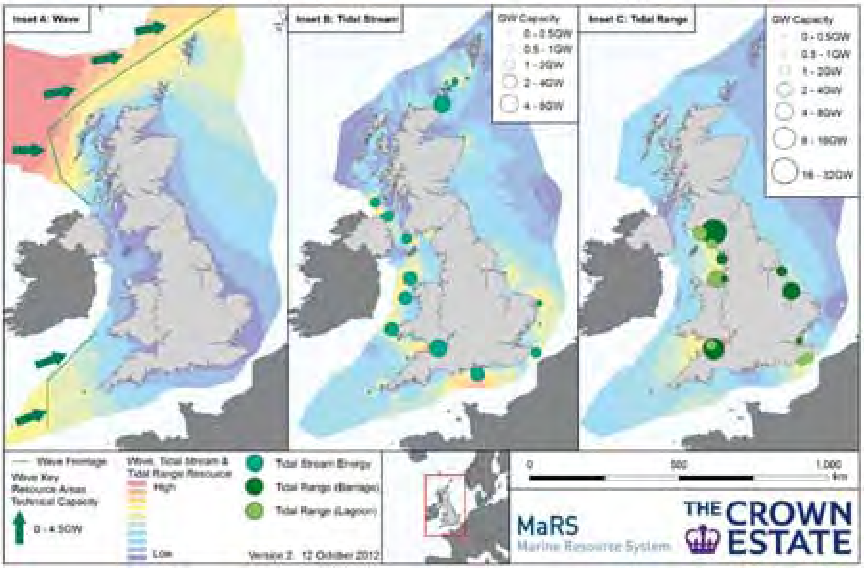


FIGURE 2: Distribution of UK wave and tidal energy resources

UK wave and tidal energy resources

In October 2012 The Crown Estate published new findings about the theoretical size and distribution of wave, tidal stream and tidal range energy resources around the UK. The resources are estimated to be follows:

- Wave: 69 TWh/year (27 GW)
- Tidal stream: 95 TWh/year (32 GW)
- Tidal range (barrage schemes): 96 TWh/year (45 GW)
- Tidal range (lagoon schemes): 25 TWh/year (14 GW)

For further details, see the UK Wave and Tidal Key Resource Areas Project - Summary Report, available to download from The Crown Estate website[11].

[11] *See http://www.thecrownestate.co.uk/news-media/news/2012/new-report-shows-extent-of-uk-wave-and-tidal-resources/*

First array investments

In January 2013, The Crown Estate announced that we are interested in investing in first array wave and/or tidal stream projects. We are considering investing up to £20m (US $31.7m) in total in two projects, alongside other companies and in parallel with government grant support. To be eligible, projects must involve an array of devices with a total installed capacity of 3 MW or greater, already have a Crown Estate agreement for lease, have or soon obtain statutory consents and grid connection agreements and realistically be expected to reach final decisions for capital investment by March 2014.

Our intentions in investing are:

- To make an acceptable commercial return, in line with our vires (powers); and
- To catalyse investments in first array projects by others, by virtue of sharing risk exposure and reducing the amount of capital others have to invest.

A guidance document which provides further information is available on our website[12].

[12] *See http://www.thecrownestate.co.uk/news-media/news/2013/looking-to-invest-in-wave-and-tidal-energy-arrays/*

06/ STATISTICAL OVERVIEW OF OCEAN ENERGY IN 2012

The information provided in this section refers to the year 2012 and was compiled from information provided by each delegate member.

6.1 WORLDWIDE OCEAN POWER INSTALLED CAPACITY

		CAPACITY [KW]	
COUNTRY	RESOURCE	INSTALLED	CONSENTED PROJECTS
Belgium	Wave power		*20000*
Canada	Tidal and ocean currents (and river current)	*250*	*5500*
	Tidal Range Power (Barrage)	*20000*	*0*
China	Wave Power	*190*	*2400*
	Tidal and ocean currents	*110*	*3700*
	Tidal Power	*3900*	*200*
Denmark	Wave Power	*250*	
New Zealand	Wave Power	*2 x 20 (one in Oregon)*	*220 (1 project)*
	Tidal Power	-	*21000 (2 projects)*
Netherlands	Tidal and ocean currents	*100*	*5000*
	Salinity Gradient	*10*	*50*
Norway	Salinity Gradient	*4*	
Portugal	Wave Power	*300 + 400*	
Republic of Korea	Wave Power		*500*
	Tidal and ocean currents	*1*	
	Tidal Power	*254*	
Spain	Wave Power	*296*	*140*
Sweden	Wave Power	*150*	*10000*
	Tidal and ocean currents		*7.5*
United Kingdom	Wave Power	*4,340*	*Various test deployments*
	Tidal and ocean currents	*6,700*	*Various test deployments*

6.2
OPEN SEA TESTING INFRASTRUCTURES

COUNTRY	TEST SITE NAME	TEST SITE PROMOTER/ MANAGER	LOCATION	GRID CONNECTION	STATUS
Belgium	FlanSea test site at Ostend	Port of Ostend	Ostend, Belgium	No	Ready
Canada	FORCE (Fundy Ocean Research Centre for Energy)	FORCE manages the demonstration site, with funding from the Federal and Provincial Government as well as the private sector	Minas Passage (Nova Scotia)	Ready	Operational
China	Wave Energy and Tidal Current Energy Test Site (Phase I)	National Ocean Technology Center	Chengshantou (Shandong Province)	Yes (64 MW)	Under planning and design
Denmark	DanWEC	DanWEC	North Sea, Hanstholm	Planned in 2015	Operational
	Nissum Bredning	Aalborg University	Benign site	Yes (0.3MW)	Operational
Ireland	Galway Bay (1:4 scale)	Marine Energy Institute	Galway Bay	No	Existing
	Atlantic Marine Energy Test Site (AMETS)	Sustainable Energy Authority of Ireland	West of Belmullet in County Mayo	Yes	Planned
New Zealand	NZ Marine Energy Centre	AWATEA and HERA	Wellington region	1 MW planned	Planned (2015)
Netherlands	Tidal Testing Centre	TTC/NIOZ/ECN	Sluice gates in the Afsluitdijk	Yes	In operation
	Tidal Testing Centre	TTC/NIOZ/ECN	Floating structure near island of Texel	Yes	Planned (2013)
	Tidal Testing Centre	TTC/NIOZ/ECN	Push testing in open water with a barge	No	In operation
	Grevelingen Tidal Test Centre	Oranjewoud	In Grevelingendam, Zeeland	Yes	Planned (2013)
Portugal	Oceanplug	REN/ENONDAS	S. Pedro de Moel	Yes	Planned
Spain	Bimep	Promoter: EVE	Armintza, Bilbao	Yes (20MW)	Planned (2013)
	PLOCAN	Promoter: PLOCAN Consortium (integrated by the *Ministry of Economy and Competitiveness and the Autonomous Government of the Canary Islands)*	Canary Islands	Yes (15 MW)	Planned (end 2013)
Sweden	Lysekil wave power research site	Uppsala University	Islandsberg	No	Existing (2006)
	Söderfors marine currents research site	Uppsala University	Söderfors, Dalälven river	No	Planned Awaiting deployment (2013)
	DGO- Deep Green Ocean	Promoter: Minesto	Strangford Lough, UK	No	Existing
United Kingdom	EMEC	Neil Kermode	Orkney, Scotland	Yes (11MW)	Existing
	WaveHub	Claire Gibson	Hayle, Cornwall	Yes (20MW)	Existing
	FabTest	Falmouth Harbour Commissioner	Falmouth, Cornwall	No	Existing
	Solent Ocean Energy Centre	Isle of Wright Council	St. Catherine's Point, Isle of Wright	Yes (20MW)	Planned (construction to begin 2015)

6.3 ELECTRICAL UTILITIES INVOLVED IN RESEARCH & DEVELOPMENT AND DEMONSTRATION

COUNTRY	NAME OF UTILITY	TYPE OF INVOLVEMENT
Belgium	Electrabel (Suez GDF)	Planning project development
Canada	NALCOR – Newfoundland and Labrador	Technology development for microgrid management
	EMERA / Nova Scotia Power	Open Hydro investor, technology demonstrator, planning project development
	Hydro Quebec	Engagement with technology demonstrations
	Ontario Power Authority	Waterpower Feed in Tariff for project development
	Manitoba Hydro	Access to site for R&D and technology demonstration
	BC Hydro	Standing offer amended to allow technology demonstration; site access for technology demonstration of river current
China	China Longyuan Power Group Corporation Limited	R&D
	Datang Fujian Power Generation Co., Ltd.	technology demonstration
	Datang Shandong Power Generation Co., Ltd.	technology demonstration
	Huaneng Renewables Corporation Limited	project development
Denmark	Dong Energy	Partnership with Wavestar and Floating Power Plant
Germany	RWE Innogy	Joint venture partner of Voith Hydro Ocean Current Technologies. Cooperation agreement with MCT/Siemens for a 10 MW current turbine demonstration project (Anglesey-Skerries)
	EON	100 MW wave power installations in Crown Estate leasing round 1through EON UK
Ireland	Electricity Supply Board	Through its subsidiary, ESBI, the ESB has an active programme of activities designed to support the introduction of OE. ESBI participates in the development of a number of wave and tidal technologies in Ireland and elsewhere. ESBI also works to develop the AMETS open ocean wave test facility. The ESB is lead partner in developing the Westwave 5MW demonstration project, to be operational in 2015.
	Bord Gais Eireann (BGE)	In 2012 BGE was awarded a lease for the development of a 100MW tidal energy project, using Open Hydro technology, in Northern Ireland.
Mexico	CFE	Pilot projects
Netherlands	Delta NV	Engaging with project and technology developers on tidal opportunities in the region of Zeeland, PPAs
	Eneco	Tidal barrage system in Brouwersdam (expressed interest), PPAs
	Greenchoice	Low head hydro sites throughout the Netherlands, PPAs
New Zealand	Todd Energy	Majority owner of Crest Energy Kaipara Limited (owner of consented project for 200 x 1 MW tidal turbines in Kaipara Harbour
Norway	Arendal Fossekompani	Part owner of tidal/current energy concept Flumill
	Statkraft AS	Develops osmotic power
	Hammerfest Energi AS	Part owner of Hammerfest Strøm AS
	Dalane energi	Supports Langlee wave concept
Republic of Korea	Korea Water Resources Corporation (K-water)	Operation of Shihwa tidal barrage power plant
	Korea East-West Power Co., Ltd.	Operation of Uldolmok tidal current pilot plant
	Korea Western Power Co., Ltd.	Feasibility study on Garorim tidal barrage power site
	Korea Hydro and Nuclear Power Co., Ltd.	Feasibility study on Incheonman tidal barrage power site
	Korea Midland Power Co., Ltd.	Feasibility study on Ganghwa tidal barrage power site
	Hyundai Heavy Industry Co., Ltd.	Full-scale demonstration of 1MW tidal current device
	Korea Electric Power Corporation	Prototype demonstration of attenuator with liquid column oscillator. Basic research on OTEC utilizing discharged water from power plant
Spain	IBERDROLA	R&D, technology demonstration and project development.
	REPSOL	R&D
	FCCE	Technology Demonstration
Sweden	Fortum	The Sotenäs Project is partly funded by the utility Fortum.
	Vattenfall	CFE II is partly funded by the utility Vattenfall
	Statkraft	CFE II is partly funded by the utility Statkraft
United Kingdom	EoN	Technology Demonstration/Project Development
	Scottish Power Renewables	Technology Demonstration/Project Development
	S cottish and Southern Electric	Technology Demonstration/Project Development
	Vattenfall	Technology Demonstration/Project Development

NEW CHAIRMAN'S BIOGRAPHY

MR. JOSÉ LUIS VILLATE
OES Chairman 2013 - 2014

Jose Luis Villate received the B.S. degree in physics in 1991 and a M.Sc. degree in advanced manufacturing technologies in 1992 both from the University of the Basque Country, Spain. From 1992 until 2010, he worked with Robotiker on topics related to electronics, digital control systems and power converters for the integration of renewable energy sources into the grid. In 2011, Robotiker and other research centres merged into TECNALIA, the biggest private research organisation in Spain, where Jose Luis Villate is currently the Director of the Marine Energy Department. He is working on several R&D projects concerning ocean energy with both private and public funding, including several European projects. Between 1998 and 2000, he was a lecturer of industrial control at the Engineering School of Deusto, Bilbao. Since 2008, Jose Luis Villate has coordinated and lectured the marine energy module of a master on renewable energy organized by CSIC. He is member of the Scientific Committee of ICOE (International Conference on Ocean Energy) and chaired ICOE2010. He chairs the Spanish Standardisation Committee on Marine Energy and he is member of the International Technical Committee TC114. He is the Spanish member and chairman of OES (the Implementing Agreement on Ocean Energy Systems of the International Energy Agency). He is member of the Board of Directors of the European Ocean Energy Association. He is the author or co-author of more than 40 papers and conference communications in national and international forums. He is the holder of four patents, three of which in the renewable energy field.

APPENDIX 1
CONTRACTING PARTIES TO OES

YEAR OF SIGNATURE	COUNTRY	CONTRACTING PARTY
2001	Portugal	Laboratório Nacional de Energia e Geologia (LNEG)
	Denmark	Ministry of Transport and Energy, Danish Energy Authority
	United Kingdom	Department of Energy and Climate Change (DECC)
2002	Japan	Saga University
	Ireland	Sustainable Energy Authority of Ireland (SEAI)
2003	Canada	Natural Resources Canada
2005	United States of America	United States Department of Energy (DOE)
2006	Belgium	Federal Public Service Economy
2007	Germany	The Government of the Federal Republic of Germany
	Norway	The Research Council of Norway
	Mexico	The Government of Mexico
2008	Spain	TECNALIA
	Italy	Gestore dei Servizi Energetici (GSE)
	New Zealand	Aotearoa Wave and Tidal Energy Association (AWATEA)
	Sweden	Swedish Energy Agency
2009	Australia	Oceanlinx Pty Ltd
2010	Republic of Korea	Ministry of Land, Transport and Maritime Affairs
	South Africa	South African National Energy Institute (SANERI)
2011	China	National Ocean Technology Centre (NOTC)

Status at 31 December 2012

APPENDIX 2
MEMBERSHIP OF THE EXECUTIVE COMMITTEE

2009 / 2012

CHAIRMAN
Dr. John Huckerby
AWATEA / New Zealand

VICE-CHAIR
Mr. Eoin Sweeney
SEAI / Ireland

VICE-CHAIR
Mr. Jose Luis Villate
TECNALIA / Spain

SECRETARY
Dr. Ana Brito e Melo
WavEC - Offshore Renewables
Portugal

2013 / 2014

CHAIRMAN
Mr. Jose Luis Villate
TECNALIA / Spain

VICE-CHAIR
Mr. Eoin Sweeney
SEAI / Ireland

VICE-CHAIR
Mr. Michael Reed
DOE / USA

SECRETARY
Dr. Ana Brito e Melo
WavEC - Offshore Renewables
Portugal

DELEGATES

AUSTRALIA
Dr. Alex Wonhas
CSIRO

BELGIUM
Dr. Ludovic Mouffe
Federal Public Service Economy
Alternate
Mr. Pieter Mathys
Ghent University

CANADA
Ms. Tracey Kutney, P. Eng.
Natural Resources Canada

CHINA
Mr. Xia Dengwen
National Ocean Technology Center, SOA
Alternate
Mr. Lin Cui
National Ocean Technology Center, SOA

DENMARK
Mrs. Hanne Thomassen
Energistyrelsen
Alternate
Dr. Kim Nielsen
Ramboll

GERMANY
Mr. Ullrich Bruchmann
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
Alternate
Mr. Jochen Bard
Fraunhofer Institute for Wind Energy and Energy System Technology IWES

IRELAND
Mr. Eoin Sweeney
Sustainable Energy Authority of Ireland
Alternate
Dr. Tony Lewis
Hydraulics and Maritime Research Centre, University College Cork

ITALY
Mr. Gerardo Montanino
Gestore dei Servizi Energetici (GSE)
Alternate
Prof. António Fiorentino
Ponte di Archimede International

JAPAN
Dr. Yasuyuki Ikegami
Institute of Ocean Energy, Saga University
Alternate
Dr. Shuichi Nagata
Institute of Ocean Energy, Saga University

KOREA
Dr. Lae-Hyung Hong
Ministry of Land, Transport and Maritime Affairs
Alternate
Dr. Keyyong Hong
Korea Ocean Research and Development Institute

MEXICO
Dr. Sergio Alcocer
Instituto de Ingeniería UNAM
Alternate
Dr. Gerardo Hiriart
Energias Alternas, Estudios y Proyectos SA de CV

NEW ZEALAND
Dr. John Huckerby
AWATEA
Alternate
Mr. Nick Eldred
AWATEA

NORWAY
Mr. Harald Rikheim
Statkraft SF
Alternate
Mr. Tore Gulli
Fred Olsen Ltd

DELEGATES

PORTUGAL
Dr. Paulo Justino
Laboratorio Nacional de Energia e Geologia (LNEG)
Alternate
Prof. António Falcão
Instituto Superior Técnico

SOUTH AFRICA
Dr Thembakazi Mali
SANEDI
Alternate
Ms. Kubeshnie Bhugwandin
Eskom Research, Testing & Demonstration

SPAIN
Mr. Angel Chamero Ferrer
Ministerio de Industria, Turismo y Comercio
Alternate
Mr. José Luis Villate
TECNALIA

SWEDEN
Dr. Maja Wänström
Swedish Energy Agency
Alternate
Ms. Angelica Pettersson
Swedish Energy Agency

UK
Mr. Trevor Raggatt
Department of Energy and Climate Change (DECC)
Alternate
Mr. Henry Jeffrey
The University of Edinburgh

USA
Mr. Michael Reed
U.S. Department of Energy
Alternate
Mr. Robert Thresher
National Wind Technology Center

APPENDIX 3
EXECUTIVE COMMITTEE MEETINGS

PAST MEETINGS

MEETING	DATE	PLACE	
1	19 October 2001	IEA, Paris	France
2	21 - 22 March 2002	London	UK
3	31 October 2002	Brighton	UK
4	4 March 2003	Paris	France
5	15 - 16 September 2003	UCC, Cork	Ireland
6	26 - 27 February 2004	INETI, Lisbon	Portugal
7	4 - 5 November 2004	DEA, Copenhagen	Denmark
8	4 March 2005	IEA, Paris	France
9	16 - 17 November 2005	EC, Brussels	Belgium
10	1 - 3 May 2006	Vancouver, BC	Canada
11	14 - 15 November 2006	INETI, Lisbon	Portugal
12	20 - 21 March 2007	UNAM, Mexico City	Mexico
13	16 - 17 October 2007	Messina	Italy
14	15 - 16 April 2008	New York city	USA
15	13 - 14 October 2008	Ifremer, Brest	France
16	30 - 31 March 2009	Bilbao	Spain
17	4 - 5 September 2009	Statkraft, Oslo	Norway
18	22 - 23 April 2010	Wellington	New Zealand
19	30 Sep - 1 Oct 2010	Dublin	Ireland
20	26 - 27 April 2011	Washington DC	USA
21	13 - 14 September 2011	Madeira	Portugal
22	17 – 18 May 2012	Daejeon	Korea
23	22 – 23 October 2012	Aalborg	Denmark

PLANNED MEETINGS

MEETING	DATE	PLACE	
24	14 – 15 May 2013	Guangzhou	China
25	21 – 24 October 2013	Cape Town	South Africa

APPENDIX 4
COMPLETED PROJECTS

NAME	ANNEX II - DEVELOPMENT OF RECOMMENDED PRACTICES FOR TESTING AND EVALUATING OCEAN ENERGY SYSTEMS
OBJECTIVE	The objective of this Annex was to develop recommended practices for testing and evaluating ocean energy systems (wave and marine currents). There are a number of different resource types within ocean energy systems (including waves, tidal range, tidal and ocean currents, salinity gradients, OTEC and hydrothermal vents) and several different approaches to extracting energy from each resource type. The present lack of technology convergence creates difficulty in comparing systems. Annex II attempted to address this issue by providing guidelines, with the intent of laying the groundwork for the future establishment of standards and protocols, for theoretical, model and prototype testing, preliminary cost assessments and the presentation of results.
OPERATING AGENT	Dr. Kim Nielsen, Ramboll – Denmark
DURATION	The Annex was set up in 2001 to address laboratory testing and, in 2006, the Executive Committee agreed to extend the Annex to address prototype testing. The Annex was concluded in March 2011.
REPORTS	***Development of Recommended Practices for Testing and Evaluating Ocean Energy Systems, Summary Report*** K. Nielsen (2010) ***Generic and Site-Specific Wave Data*** K. Nielsen and T. Pontes (2010) ***Guidelines for the Development & Testing of Wave Energy Systems*** B. Holmes (2010) ***Guidelines for the design Basis of Marine Energy Converters*** P. Davies (2009) ***Guidance for Assessing Tidal Current Energy Resources*** Cornett (2008) ***Tidal Energy Development Protocol*** S. Bahaj, L. Blunden and A. A. Anwar (2008) ***Preliminary Wave Energy Device Performance Protocol*** G. Smith and J. Taylor (2007) ***Preliminary Tidal-current Energy Device Performance Protocol*** S. J. Couch and H. Jeffrey (2007) All reports are available at ***www.ocean-energy-systems.org***

NAME	ANNEX III - INTEGRATION OF OCEAN ENERGY PLANTS INTO DISTRIBUTION AND TRANSMISSION ELECTRICAL GRIDS
OBJECTIVE	The overall aim of this Annex is to provide a forum for enabling co-operative research activities related to integration of wave and tidal current power plants into electrical grids.
OPERATING AGENT	Dr. Gouri Bhuyan, Powertech Labs – Canada
DURATION	This Annex was commissioned in 2008 and was concluded in March 2011
REPORTS	***Potential Opportunities and Differences Associated with Integration of Ocean Wave and Marine Current Energy Plants in Comparison to Wind Energy*** J. Khan, G. Bhuyan and A. Moshref (2009) ***Key Features and Identification of Needed Improvements to Existing Interconnection Guidelines for Facilitating Integration of Ocean Energy Pilot Projects*** J. Khan, G. Bhuyan, and A. Moshref (2009) ***Dynamic characteristics of wave and tidal energy converters & a recommended structure for development of a generic model for grid connection*** D. O' Sullivan, D. Mollaghan, A.Blavette and R.Alcorn (2010) I***ntegrating Wave and Tidal Current Power: Case Studies through Modelling and Simulation*** M. S. Múgica, F. S. Fernandez , J. L. Mendia , J. Khan, D. Leon, S. Arabi, A. Moshref, G. Bhuyan, A. Blavette, D. O'Sullivan, R. Alcorn (2011) All reports are available at ***www.ocean-energy-systems.org***

APPENDIX 5
TERMINOLOGY FOR OES

TERM	DEFINITION
ANNEX	addendum to an Implementing Agreement (IA) and an integral part thereof, which sets forth the manner, including the financial undertakings and other means of support, by which the activities (sometimes called Tasks) of the Annex will be implemented by the Participants.
CERT	Committee on Energy Research and Technology is one of the IEA Standing Committees. Comprised of representatives from each IEA Member country and supported by the Secretariat, the CERT formulates and supervises the execution of the IEA's R&D programme, including national programme reviews, technology reviews, studies on strategic planning and oversees the IAs. The CERT is supported by four Working Parties on Renewable Energy, EndUse Efficiency, Fossil Fuels, and Fusion Power.
COMMON FUND	fund established by the Executive Committee into which the financial contributions of the Participants are placed.
CONTRACTING PARTY (CP)	Signatory of an IA.
EXECUTIVE COMMITTEE (EXCO)	the body, comprising representatives of all the Participants in an Implementing Agreement, which supervises the work of the IA and is the decisionmaking body of the IA.
EXCO REPRESENTATIVE	the individual designated by each Participant to be the Participant's representative on the Executive Committee.
IMPLEMENTING AGREEMENT (IA)	the contractual relationship established by at least two IEA Member countries and approved by the Governing Board to carry out programmes and projects on energy technology research, development and deployment.
OPERATING AGENT (OA)	the legal entity designated in the IA text, or by the ExCo, or by the Participants in an Annex, to manage part or all of the Programme of Work of an IA and/or of its Annexes.
PROGRAMME OF WORK	the overall plan of activities determined by the Executive Committee to be implemented under the Implementing Agreement.
TASK	particular collaborative R&D activity within the IA's Programme of Work in which some, but not all, Participants may choose to participate. The activity, and the means of participation in the activity, is described in an Annex to the IA.
WORKING PARTY (WP)	one of the current Working Parties mandated by the CERT to carry out specified work in energy technology and to initiate, evaluate and review IAs in its special field. At present, the Working Parties are: the Working Party on Energy EndUse Technologies (EUWP); the Working Party on Fossil Fuels (WPFF); the Working Party on Renewable Energy Technologies (REWP); and the Fusion Power Coordinating Committee (FPCC).

CONTACTS:

THE SECRETARIAT OF THE OES IS BASED AT:
WavEC - Offshore Renewables
Rua D. Jerónimo Osório, 11, 1º andar
1400-119, Lisboa - PORTUGAL
Tel: +351 21 848 2655 / Fax: +351 21 848 1630

OCEAN ENERGY SYSTEMS (OES)

www.ocean-energy-systems.org