IEA | OES
Ocean Energy Systems

ANNUAL REPORT > 2004

INTERNACIONAL ENERGY AGENCY

IMPLEMENTING AGREEMENT ON OCEAN ENERGY SYSTEMS

INTERNACIONAL ENERGY AGENCY

ANNUAL REPORT > 2004

IMPLEMENTING AGREEMENT ON OCEAN ENERGY SYSTEMS

Published by	IEA-OES Executive Committee
Acting Editor	IEA-OES
Designed by	2 & 3 D Design e Produção, Ltd
Circulation	500 exemplars
Printed by	Taligraf

CONTENTS

FOREWORD

by Teresa Pontes
2004 Chair of the IEA-OES

Teresa Pontes, Chair 2004
IEA-OES _ Ocean Energy Systems Executive Committee

In 2004 progress towards market deployment of wave energy and marine currents energy technologies continued to be witnessed. Important achievements were the sea tests of the first three offshore prototypes. These are the 750kW Pelamis in Scotland, the 1MW AWS prototype off northern Portugal and the 1:4.5 scaled Wave Dragon prototype tests in Denmark that had started during the previous year. In Australia the preparation for the deployment of the near-shore parabolic-wall oscillating-water-column in Port Kembla approached the end, its deployment being planned for 2005. Demonstration of marine current turbines continued. In the UK the bottom-fixed horizontal axis Seaflow 300 kW turbine pursued tests in North Devon as well as the reciprocating wing Stringray. In Italy the testing of the 130 kW ENERMAR vertical axis turbine in the Straight of Messina continued providing further development. Except for the Stingray, the results of the above tests gave the developers reasons to plan starting soon pre-commercial activity, having in view to approach competitiveness with electricity production from other renewable energy sources such as wind.

In addition to the demonstration of the above systems that has been widely publicized, development of other wave energy and marine current energy devices is taking place in several countries, in some cases reaching even the sea testing of prototypes. It is then expected that information on these new technologies will start to be disseminated in the near term.

As a consequence of the rise of oil and gas prices, the increasing signals of climate change due to CO_2 emissions and the progress of wave and marine current energy technologies, large companies and funding institutions are starting to be attentive and invest in these technologies. This is a change from previous years when the leading role of the industrial development was taken by SMEs. Recently governments, namely the UK at national and regional levels, restarted to set up policies and measures to support technology development and market creation which had not happened since the early phase of wave energy R&D in the 1970s and early 1980s.

Most of wave energy and marine current energy development is being performed in Europe which is partly a result of the funding and co-ordination by the European Commission. However, development also takes place elsewhere namely in Asia and in North and South America in addition to Australia.

The oceans contain energy from sources other than wind-generated waves and marine currents. The most developed technologies concern tides and ocean thermal vertical gradient. The tidal energy resource is mapped and the technology is considered mature since in France the La Rance 240 MW tidal power plant in Normandy became operational in 1968, and two smaller schemes operate in Canada and Russia. There is news that in one or more Asian countries the construction of tidal plant is being planned. The Ocean Thermal Energy Gradient (OTEC) can be harnessed in tropical areas where the annual average of the temperature difference between surface and deep water reaches more than 22o C. Demonstration started in the 1930s by France, and continued in USA and Japan till the end of 1980s. A renewed interest has been announced by USA and Japan. Saga University, the new Japanese contracting party to this Implementing Agreement, has been very active in this technology thus bringing a new capacity for the IEA-OES.

It is then with good hope that we are facing the near future.

1 THE IMPLEMENTING AGREEMENT ON OCEAN ENERGY SYSTEMS

1.1 Introduction

The International Energy Agency (IEA) was established as an autonomous body within the Organisation for Economic Co-operation and Development (OECD) in 1974 to implement an international energy programme.

The IEA provides a structure for international co-operation in energy technology research and development (R&D) and deployment. Its purpose is to bring together experts in specific technologies who wish to address common challenges jointly and share the fruit of their efforts.

The IEA's programme of International Energy Technology Co-operation includes a mechanism called an "Implementing Agreement". There are currently 40 Implementing Agreements under the IEA International Energy technology Co-operation Framework, grouped in the following domains:

- Fossil Fuels
- **Renewable Energies and Hydrogen**
- End-use Technologies (Buildings, Industry and Transport)
- Fusion Power
- Cross-sectional activities

Nine IEA Implementing Agreements cover the broad spectrum of renewable energy technologies:

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

Participating Countries 1.2

The IEA-OES was started in 2001 by Denmark, Portugal and the UK. Ireland and Japan joined in 2002 and Canada and the European Commission joined in early 2003. During 2004 the following countries and designated entities were:

Contracting Parties

ENTITY	COUNTRY
POWERTECH LABS INC.	CANADA
MINISTRY OF ECONOMIC AND BUSINESS AFFAIRS, DANISH ENERGY AUTHORITY	DENMARK
COMMISSION OF EUROPEAN COMMUNITIES	EUROPEAN COMMISSION
SUSTAINABLE ENERGY IRELAND (SEI)	IRELAND
SAGA UNIVERSITY(1)	JAPAN
INSTITUTO NACIONAL DE ENGENHARIA TECNOLOGIA E INOVAÇÃO I.P. (INETI)	PORTUGAL
DEPARTMENT OF TRADE AND INDUSTRY (DTI)	UNITED KINGDOM

Table 1 | Contracting Parties to the Agreement IEA-OES (status: end 2004)

(1) JAMSTEC, the initial contracting party from Japan, withdrew from the IA-OES during 2004, and the process of change of contracting party to IOES - Saga University was begun.

Interest in increasing IEA-OES participation is being encouraged, and prospective members have been invited to attend IEA-OES Executive Committee (ExCo) meetings. The USA was invited to join the Implementing Agreement in 2004 and is expected to complete the process of signing the Agreement in 2005.

1.3 IEA-OES Objectives

This Implementing Agreement was established with the **mission** of enhancing international collaboration to make ocean energy technologies a significant energy option in the mid-term future. Through the promotion of research, development, demonstration and information exchange and dissemination, the Agreement's **objective** is to lead to significant deployment and commercialization of ocean energy technologies.

The present work programme focuses on ocean waves and marine currents which are the ocean energy technologies that have been the object of the strongest R&D and demonstration effort in the last fifteen years and are considered to present the best prospects for competitive deployment in the short- to medium-term.

The **strategy** of the IEA Ocean Energy Systems Implementing Agreement Programme is based on the following objectives:

> To actively encourage and support the development of networks of participants involved in research, development, demonstration, prototype testing and deployment, and to provide for the effective exchange of information on ocean energy.

> To promote the development and utilisation of technologies for enhanced sustainable energy production from the ocean.

> To promote the involvement of industry and utilities in the IEA Ocean Energy Systems Programme.

> To promote interactions with other global, multilateral and national energy implementation programmes.

IEA-OES Work Programme

1.4

The Work Programme to be undertaken by the Contacting Parties is established under Annexes to the Implementing Agreement, setting out a Task and describing an agreed set of activities to be undertaken by the participants in this Task. The terms Task and Annex are often used interchangeably by this Implementing Agreement.

Participants in the IEA-OES are currently working on two cooperative research Tasks:

Annex I: Review, Exchange and Dissemination of Information on OES
Operating Agent: Instituto Nacional de Engenharia Tecnologia e Inovação I.P. (INETI).
The Work Plan of Annex I started in 2002 and was designed to run for a period of five years.

Annex II: Development of Recommended Practices for Testing and Evaluating OES
Operating Agent: Danish Energy Authority, Ministry of Economic and Business Affairs of Denmark is designated as Operating Agent acting through RAMBOLL.
The Work Plan of Annex II was initially designed for two years and was prolonged to three years in the 5th ExCo meeting.

Efforts to expand the activities in the Agreement have continued during 2004. The Executive Committee is considering additional task proposals under this Annex.

Annex I: Review, Exchange and Dissemination of Information on OES
The objective of Annex I is to collate, review and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of ocean energy systems with a view to facilitating further development and adoption of cost-effective ocean energy systems through improved access to available information.

The participants in this Task update and exchange annually information on ocean energy systems research, development, deployments and other activities of interest. Participants further analyse this information to develop joint summary assessments of trends in ocean energy exploitation including incentives and regulations.

Annex II: Development of Recommended Practices for Testing and Evaluating OES
The objective of Annex II is to develop recommended practices for testing and evaluating ocean energy systems and, in this way, to improve the comparability of experimental results. This is done by collecting and analysing information on testing facilities and testing procedures. Standards for presentation of technical design and data and for assessment of system performance are produced.

THE EXECUTIVE COMMITTEE

2.1 Meetings

Figure 1 | 6th ExCo meeting participants

From left to right:

In front:	Tony Lewis (Ireland ExCo alternate)
	Katrina Polaski (Ireland ExCo member)
	Yasushi Tsuritani (Japan ExCo member)
	Ana Brito Melo (Portugal ExCo secretary)
	Petter Hersleth (Norway ExCo observer)
2dn line:	Cynthia Rudge (Australia ExCo observer)
	Robert Tresher (USA ExCo observer)
	Gouri Bhuyan (Canada ExCo member)
Behind:	Peter Goldman (USA observer)
	Philippe Schild (EC ExCo member)
	Alla Weistein (Ireland ExCo observer)
	António Falcão (Portugal ExCo alternate)

The work program within the Implementing Agreement is co-ordinated by an Executive Committee (ExCo) consisting of a Member and an Alternate Member from each Member-Country. The ExCo meets twice every year to exchange information on ocean energy activities, to review ongoing tasks under the Agreement, to discuss new Annexes proposed by participants and to approve the budget to administer the Agreement.

The following ExCo meetings were held during the year 2004:

> 6TH EXCO MEETING IN LISBON, PORTUGAL ON FEBRUARY 26th - 27th

Twelve participants attended including 5 Members and 7 Observers (1 from Australia, 1 from Japan, 1 from Brasil, 1 from Norway and 3 from USA). Denmark and the United Kingdom could not attend the meeting.

> 7TH EXCO MEETING IN COPENHAGEN, DENMARK ON NOVEMBER 4th - 5th

All members were presented in this meeting. The number of participants was 14, 8 Members and 6 Observers (1 from Japan, 1 from Norway, 1 from Italy, 1 from UK and 2 from USA).

During 2004, Dr. Teresa Pontes from Portugal was the chair of this ExCo and Mrs. Katrina Polaski from Ireland was Vice-Chair. In the last 2004 ExCo meeting Mrs. Katrina Polaski was elected Chair for 2005 and Dr. Teresa Pontes was elected Vice-Chair.

The contact details for the ExCo members can be found in Appendix 1.

A secretariat assists the ExCo in planning the meetings, assisting the members, providing information to the IEA Secretariat and public in general, updating the website of the IEA-OES and preparing the annual report, the semi-annual newsletter, and any other material requiring dissemination. The ExCo secretariat is based in the Wave Energy Centre, Portugal, and is run by Dr. Ana Brito Melo. Administrative matters and management of the common fund of the IEA-OES are managed by INETI.

2.2 Changes in ExCo membership and New Members

Japan: JAMSTEC, the initial contracting party from Japan, has withdrawn from this IA and will be replaced by IOES - Saga University. The process of changing the contracting party started in 2004.
UK: Mr. Gary Shanahan from DTI is the new Delegate representing the UK, replacing Mr. John Overton.

Interest from potential Member Countries continued to be strong throughout this year. The USA has accepted an invitation to join the IEA-OES. Observers from Italy and Norway attended ExCo meetings, and the Chair was in contact with potential Contracting Parties in these countries and in Brasil. In 2004, Italy and Norway were formally invited by the Executive Committee to be Members of the IEA-OES, and the ExCo agreed to invite Brasil.

Figure 2 | 7th ExCo meeting participants

From left to right:

Yasuyuki Ikegami (Japan ExCo member)
Keisuke Saruwatari (Japan ExCo observer)
Gouri Bhuyan (Canada ExCo member)
Tony Duffin (UK ExCo observer)
Tony Lewis (Ireland ExCo alternate)
Kouichi Sakata (Japan ExCo observer)
Antonio Fiorentino (Italy ExCo observer)
Gary Shanahan (UK ExCo member)
Stanley Calvert (US ExCo observer)
Teresa Pontes (Portugal ExCo member)
Petter Hersleth (Norway ExCo observer)
Katrina Polaski (Ireland ExCo member)
Philippe Schild (EC ExCo member)
Jan Bünger (Denmark ExCo member)
Mike Robinson (US ExCo observer)
Ana Brito Melo (Portugal ExCo secretary)
Kim Nielsen (Denmark ExCo alternate)

2.3 Fund Administration

Two methods exist for financing Implementing Agreements:

> Cost-sharing: the Member Countries contribute to a common fund for conducting research projects and information exchange.

> Task-sharing: the Member Countries devote specified resources and personnel to conduct an agreed work programme.

All activities under the two Annexes of this Implementing Agreement are task-shared. Member Countries share the cost of administration for the ExCo through annual contributions to the common fund.

The common fund is managed by INETI, Portugal. This fund supports the secretariat and other expenditures approved by the ExCo in the annual budget. These expenditures include the travel expenses for the Secretary participation in the ExCo meetings, travel expenses of the Chair representing the IEA-OES in relevant meetings for dissemination of the activities of the IEA-OES, and the production of IEA-OES publications including the Newsletter, Annual Report and other material for dissemination of the general activities.

Funds carry forward from 2002/2003 were 6,383.10 Euro and total funds received in 2004 amount to 42000 Euros with annual contribution of 7,000 Euro by each of six members (Denmark, Portugal, UK, Ireland, Canada and the European Commission). Total expenditures in 2004 were 31,973.17 Euro. This resulted in a positive balance of 16,409.93 Euro and the ExCo proposed to create a contingency reserve with this amount.

Events organized by the IEA-OES 3.1

Open Session on National activities on the IA-OES Member countries | 3.1.1

The Executive Committee organised an Open Session during the 6th ExCo meeting in Lisbon (26th February 2004) in which the national activities of some members countries in the ocean energy area were presented:

International Energy Agency – Current Issues

Peter Tulej, IEA secretariat

This presentation included an overview of the organisation of the International Energy Agency and the principal aims of the Agency, the strategy and mandate of the Renewable Energy Working Party (REWP) for 2004 – 2006, the implementing agreements structure, and potential collaborative programs. Included among the projects being developed under the IEA is the collection of statistical information on renewable energy and the development of a database on Renewables Energy policy representing an extensive source of verified information on policies and measures for the analysis of best trends and practices regarding renewable energy in the IEA Member countries.

OPEN SESSION ON NATIONAL ACTIVITIES
26th February 2004

International Energy Agency – Current Issues
Peter Tulej
IEA secretariat

Portugal – R&D Technology
António Falcão
Alternate Member from Portugal

"Sustainable Energy Systems" FP6 work programme
Philippe Schild
Delegate Member from the EC

Wave Energy Centre
António Sarmento (invited speaker)
Director of the Wave Energy Centre in Portugal

Portugal – R&D Technology

António Falcão, Alternate Member from Portugal

A brief presentation concerning the scientific and technical expertise in Portugal was made, with reference to the milestones in ocean energy R&D since 1978, the present situation focusing on Portugal's strength in R&D and technology development, and finally the forthcoming actions in wave energy in Portugal.

"Sustainable Energy Systems" FP6 work programme

Philippe Schild, Delegate Member from the EC

The call launched and managed by DG Research (DG RTD) was presented with particular focus on the Expressions of Interest (EoI) related to Sustainable Energy Systems, and research activities having an impact in the medium and longer term of the FP6 Programme. The background of the Sustainable Energy Systems Work programme and the strategically important areas in which research should be concentrated was presented.

Wave Energy Centre

António Sarmento, director of the Wave Energy Centre in Portugal (invited speaker)

The Wave Energy Centre, an international non-profit organisation in Portugal was presented. The objective of this recently founded association is to support the development and implementation of Ocean Wave Energy and the companies and institutions either active in wave energy research or intending to partake in the future development of wave energy systems

Expert Meeting on "Grid Integration of Ocean Energy Systems" | 3.1.2

The Executive Committee of the IEA-OES organised an Expert Meeting during the 7th Exco meeting in Copenhagen (5th November 2005) in order to explore the issues around grid integration experienced by other renewable electricity generation technologies and how these may impact the development of ocean energy. A number of experts gave presentations to an open forum that included the ExCo members and members of the ocean energy community. The workshop provided a platform for discussing and gathering information on:

> Existing knowledge and experience on technical issues, including the impact of intermittent generation on grid operation, regarding grid integration on wind farms
> Exchange of knowledge, ideas, and experiences related to grid integration of ocean energy systems.
> Technical, economic and safety issues inherent in the grid integration process of ocean energy

The five experts presenting included:

> Dr. Ana Estanqueiro (INETI, Portugal)
> Mr. Stanley Calvert (U.S. DOE)
> Mr. Steen Beck Nielsen (SEAS, Denmark)
> Mr. Tony Duffin (Carbon Trust, UK)
> Prof. Mark O'Malley (University College Dublin, Ireland).

Dr. Gouri Bhuyan (Powertech Labs, Canada) acted as the rapporteur for the workshop.

The outcomes of the workshop were summarised by the Expert Meeting Chair, Dr Ana Estanqueiro, as follows:

The presentations covered a wide range of experiences, from the know-how achieved by integrating onshore and offshore wind parks into the grid (USA and Denmark) as well as other renewable energy sources (Portugal) to aspects only present in the conversion of ocean energy (Ireland) and the economics and strategy towards a "low carbon society" (United Kingdom).

Most authors agreed that the integration of wave and tidal current energy conversion systems has a strong similarity to the wind energy systems integration, although some technical operating characteristics of ocean devices are unique. The similarities to wind energy pointed out were:
- Impact on power quality, such as, flicker, harmonics, voltage dips, etc.
- Impact on system security of supply namely the effect on the system regulation and local generation. The disturbances of interest are thermal overloads, voltage drop/rise, frequency control, protections and transient stability among others.

However, and differently from her older sister, the wind energy, the grid integration study of the ocean energy conversion systems may pose a wider range of problems, mainly related to the variety of technologies currently being proposed. Also pointed out by some authors was the lack of modular dynamic models, as well as experimental data to validate and calibrate the few existing models.

It was concluded in this workshop that the specific problems of integrating ocean energy devices into the grid require and justify further and focused research on this issue, specially on what concerns the dynamic behaviour of the different technologies when connected to the distribution grid.

Unlike for the wind energy sector, it is not clear for the research teams involved in the grid integration of ocean conversion systems, what is the frequency content of the electric and voltage fluctuations at the connection point and their relevance to the potentially harmful flicker emissions. Deep insight into this grid impact would also contribute to rank the existing ocean energy conversion technologies and select the ones with a more positive contribution for the overall power system operation.

The storage capacity of individual ocean energy devices, if any, and their possible ability to smooth the electric power produced when compared to the irregularity of incoming waves should also be considered as a relevant part of a grid integration study.

Ana Estanqueiro, INETI

PARTICIPATION IN RELEVANT EVENTS

International Conference for Renewable Energies
June 1–4 , 2004
Bonn, Germany

European Marine Energy Centre (EMEC)
August 10-11, 2004
Orkney Islands

2004 Annual Summit of the Pacific NorthWest Economic Region (PNWER)
of North America
July 11-14, 2004
Victoria, Canada

3.2 Participation in relevant Conferences and Workshops

International Conference for Renewable Energies
June 1–4 , 2004, Bonn, Germany

This conference addressed the following main themes: i) financing instruments and market development; ii) formation of enabling political framework conditions and iii) capacity building (education, research, networks, cooperation, etc.).
The IEA organized a side event during this conference to highlight IEA activities in renewables and the Implementing Agreements were encouraged to participate in the exhibition. The Implementing Agreement on Ocean Energy Systems participated, presenting its 2003 Annual Report, the IEA-OES Newsletter and a poster.

Workshop - European Marine Test Centre
European Marine Energy Centre (EMEC)
August 10-11, 2004, Orkney Islands

The Chair of IEA-OES participated by invitation in the official opening of the European Marine Energy Centre (EMEC), located in Stromness, Orkney Islands and in the Workshop on Testing and Certification. In this workshop the Chair made a brief presentation of the activities that have been and are planned to be developed within Annex II – Development of Recommended Practices for Testing and Evaluating Ocean Energy Systems. It was planned to establish collaboration between EMEC and IEA-OES to jointly pursue these activities.

2004 Annual Summit of the Pacific NorthWest Economic Region (PNWER) of North America

July 11-14, 2004, Victoria, Canada

A special session on Ocean Energy was organized and chaired by Dr. Gouri Bhuyan, the Canadian member of the IEA-OES, at the 2004 Annual summit of the PNWER as part of the Energy II- Emerging Technologies WG activities. Various action items, identified through the discussions held at the session, were approved as the Resolution 2004-8 by the PNWER Executive Committee. This resolution has been communicated to various relevant provincial, state and federal policy makers in Canada and US.

3.3 Promotion and Communication

IEA-OES Newsletter | 3.3.1

The IEA-OES Newsletter was first published in 2003. It contains information on ocean energy and has been widely distributed both within the Member Countries and at major conferences and seminars. This Newsletter is a collaborative publication of the Members who provide contributions on planned and ongoing activities and programmes. The last page of the Newsletter is dedicated to information on relevant events on ocean energy and includes the Member's contact details.

Figure 3 | Issue 3 – April 2004

In 2004 the following articles were included:

The Salinity Power project, by Ralf Jarle Aaberg, Statkraft SF

This project is co-funded by the European Commission and involves the partners Statkraft SF(Norway), Instituto de Ciência Tecnologica de Polímeros (ICTPOL) (Portugal), SINTEF (Norway), Helsinki University of Technology (Finland) and Forschungszentrum GKSS (Germany). The main objective of this project is the development of an efficient osmosis membrane that is capable of transferring large amounts of freshwater towards an osmotic pressure gradient, producing a renewable source of energy that can be extracted wherever freshwater from rivers and lakes meets the saltwater of the ocean.

The European Marine Energy Centre, by Andrew Mill, EMEC

An overall description of the Wave Test facility in Orkney was presented. EMEC is a purpose built multi-berth, grid connected test facility for full scale wave energy converters which is expected to add additional facilities to cater for tidal stream devices in 2006

The Ocean Energy Systems Workshop in British Columbia

This workshop took place on 12th March 12, 2004 with the aim of exchanging information on the current state of Ocean Energy development in British Columbia and to evaluate the needs of the stakeholders in this field. Dr. Gouri Bhuyan, the Canadian member of the IEA-OES presented the “Global Status of Ocean Energy – Renewable Energy Resources & Status in BC”. The Workshop concluded with a discussion around the economic potential of the ocean energy systems for BC, the interest of individuals & organizations in supporting this sector and the main issues to promote its development in BC and Canada. This workshop led to a subsequent formation of a national organization called “Ocean Renewable Energy Group (OREG)” in Canada.

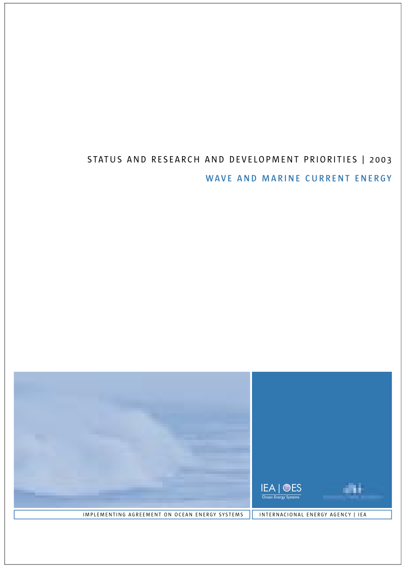
Website | 3.3.2

The website (www.iea-oceans.org) is a dissemination tool for information about the IEA-OES. It also provides dissemination of documents among the members namely to enable consulting agendas, minutes and other internal documents.

The website includes an overall description of the Implementing Agreement, the tasks, news and events on Ocean Energy, links to other related sites and available online documents including the annual reports, Task publications, and newsletters. The following reports produced under the two IEA-OES annexes are public available on the website:

Wave and marine current energy – status and research and development priorities | 2003
This report contains information on the technical, economic, environmental and social aspects of ocean energy systems (wave and tidal currents), a list of national and regional R&D programmes on a global level (considering resource, funding, activities and status), and a presentation of Ocean Energy System R&D priorities with special focus on generic research.

Development of recommended practices for testing and evaluating ocean energy systems | 2003
In addition to providing an overview of testing facilities in Member Countries where experiments of wave and marine currents energy systems can be carried out, this report provides guidelines for standards for scale model testing, presentation of results, and preliminary costs assessment.



The IEA OPEN Energy Technology Bulletin | 3.3.3

Dissemination of publications by the IEA-OES is also made through The IEA OPEN Energy Technology Bulletin (http://spider.iea.org/impagr/cip/index.htm). This newsletter disseminates the activities within the IEA's energy technology and R&D community.

4 ANNEX II ACTIVITIES

Testing and Evaluation Guidelines
By Kim Nielsen, Operating Agent of Annex II

Ocean energy systems are at the research and development and pre-commercial demonstration stage of technology development. A major challenge to developers and those supporting development in this area is that there are a number of different resource types within ocean energy systems (including waves, tides, tidal currents, salinity and thermal differentials) and several different approaches to extracting energy from each resource type. This lack of convergence creates difficulty in comparing systems as the underlying assumptions with respect to power production, generator capacity and cost statements are based on very different assumptions.

Annex II of the IEA OES attempts to address this issue by providing guidelines, with the intent to lay the groundwork for the future establishment of standards, for theoretical, model and prototype testing, preliminary cost assessments, and the presentation of results. The 2003 report, Development of Recommended Practices for Testing and Evaluating Ocean Energy Systems, is the first output from the Annex.

The first section of the report provides an overview of model testing facilities currently available in a number of member countries to the Implementing Agreement and other European countries. The descriptions of facilities are provided on a consistent basis for comparability, including consistent measurements of:

- wave tank dimensions
- wave production capability (ie. Size, speed and dimensions)
- and current production capability.

Guidelines for the description of sea conditions and the means of determining the energy available in a given sea condition are provided in section two of the report. Recommended experiments for testing wave power converters include a number of recommended wave spectrum to investigate the sensitivities of a device concept to spectral shapes, wave periods, and directional spreading as well as survivability in extreme sea states. Methods for measuring absorbed power on a number of wave power converters are also included. Results presentation and performance assessment guidelines are recommended in further sections to the report.

The annex II part 2 will look at different aspects of prototype testing such as

- Ocean based test sites for Ocean Energy Systems.
- Definition of prototype scales and testing conditions
- Power Take-off system (PTO) testing and operation.
- Control systems
- Installation methods
- Methods of operation for inspections.
- Grid connection
- Monitoring
- Data presentation and evaluation
- Cost of prototype testing

The annex will collate, analyse and present information from existing test sites within the IEA OES member group and Ocean Energy Systems being developed to a prototype scale.

5 RESEARCH AND TECHNOLOGICAL DEVELOPMENT FOR OCEAN ENERGY SYSTEM*

by Philippe Schild
Delegate member from EC (in 2004)

*This document was prepared for submission to the IEA Secretariat as background information for a one day seminar on R&D Priorities involving the Implementing Agreements for renewable energy and hydrogen which took place in March 2005.

The technologies to extract energy from the many ocean resources are early stage in comparison with other renewable energies. Investment in ocean energy R&D has been a small fraction of the total renewable R&D budget in the OECD for the past 30 years. The resource, however, is theoretically much greater than world energy demand.

In the near term, ocean energy technologies will continue prototype deployment and investigation of multi-device large scale deployments. In the medium term, these technologies may become a significant contributor to those markets adjacent to the most accessible resource. In the longer term, when hydrocarbon scarcity becomes an increasing constraint and new forms of energy transmission are justified, ocean energy could become a much more important part of the world's energy portfolio.

5.1 Current Technology Status

There is no commercially leading ocean energy conversion technology at the present time. Nevertheless, there are commercially operated power installations.

Ocean energy sources are classed into five principal categories: wave, tidal, marine current, thermal gradient and salinity gradient. Waves result from the action of the wind on the surface of the ocean. Tidal energy occurs mainly from the action of the moon's gravitational field. Marine currents are induced by the thermal and salinity gradient in addition to the tidal effect. Thermal gradient uses the temperature difference between surface water heated by solar radiation and the cold deep water. Salinity gradient utilises the pressure difference arising between fresh water and sea water.

There are only three tidal barrages around the world operated as a commercial power plant, amounting to a worldwide total of 260MW_e of installed capacity. Currently two wave power installations are operated as commercial-testing installations, cumulating around 750kW_e of peak power. Tidal current systems, OTEC installations and salinity gradient concepts have been only test prototypes.

As there are no purely commercial ocean energy plants operating (aside from tidal barrage in which there is currently limited interest in future development), learning curves and cost figures do not rest on existing experience, but on estimates. For example, wave energy systems have seen twenty years of slow development. Three studies, summarised in the final report of the European Wave Energy Thematic Network , showed that estimated electricity cost for oscillating water columns have decreased in the 20 year period by a factor of 4, from 0.40€/kWh to 0.10€/kWh. These estimates assume bulk production of components and perfect power plant behaviour that have still to be obtained. Available estimates of potential power costs for energy from offshore wave devices are in the range of 0.08 - 0.11€/kWh[1] , however it should be noted that these estimates are not current. More recent estimates of potential costs for tidal and marine current energy put prices in the range 0.045 - 0.135€/kWh[2]

[1] World Energy Council, 'Renewable Energy Sources: 2000-2020. Opportunities and Constraints', World Energy Council, London. 1993
[2] Boud, Richard, Future Energy Solutions for DTI and IEA OES Implementing Agreement, 'Wave and Marine Current Energy; status and research and development priorities', 2003

5.2 Research and Development (Past, Present and Future)

Research and technological development needs to be done to bring ocean energy technologies to maturity. Ocean energy systems are confronting the marine environment in its most energetic location, implying strong wave climate and/or strong currents and they need to fulfill the basic economic and environmental requirements including: low cost, safety, reliability, simplicity and low environmental impact.

Tidal barrage technology has not been considered in this section for two reasons. Firstly, the concept is based on mature hydropower components requiring limited research development to adapt to the marine environment. Secondly, the environmental impact on the local ecosystems would prevent wide spread deployment. An in-depth analysis of the three existing installations would however provide crucial information to help policy makers when developers come forward with such projects.

Economic viability

Economic viability is essential to attract investors and energy producers. It comes from the best compromise between a cheap design, a reliable design and the economic situation of a particular site. Predictability of power generation also plays a strong role. Simplicity comes from a good design that brings reliability and ease of manufacture and deployment.

Lowering cost will improve the economic viability and acceptability of new emerging ocean energy technologies. This aim is achieved through efficient design, the use of low cost and readily available materials and components, and economies of scale. Safety is a crucial issue for any device in a marine environment and it concerns both the device and all the marine users, human and non-human. To achieve it, deployment and construction procedures and accident prevention systems need to be efficient, reliable and safe. Reliability is required to reduce the requirement for access to the site for repairs and inspections, which will decrease the cost of operation.

A low environmental impact

A low environmental impact is a fundamental requirement to preserve the fragility of the marine ecosystems and to be a clean energy source. All ocean energy systems must be designed with consideration of the impact of a system on its environment. Nevertheless, ocean energy devices can have a positive environmental impact. An ocean energy farm consisting of multiple devices over a specified area could create a wild life sanctuary by restricting access to the site of the farm. Marine life is known also to strive on man-made structures. Furthermore, wave energy systems could be integrated into a coastal protection opportunity.

Background information

The European Wave Energy Thematic Network, WAVENET, and the IEA Implementing Agreement on Ocean Energy Systems have addressed the issue of R&D needs [3,4], broadly partitioned into non-technical and technical barriers that will need to be overcome. When the means to resolve non-technical barriers are technical, the research objectives are mentioned. The technical barriers are closely related to the ocean energy source and to the concept under development. Nevertheless, synergy between devices and across ocean energy sources exists.

The present summary describes the synergy of the research needs, as identified in the above mentioned groups, for ocean energy systems in terms of non-technical barriers common to all Ocean Energy Technologies and technical barriers for specific technologies on Wave, Tidal Current, Salinity and Thermal Gradients.

* Contribution from EC Delegate, European Commission, Directorate General Research, B-1049 Brussels, Belgium

[3] 2002 WAVENET Final report

[4] 2002 IEA Report

Figure 4 | Limpet power plant (Wavegen)

Figure 5 | Pico Power Plant, Azores, Portugal

Figure 6 | SEAFLOW (Marine Current Turbines Ltd)

Non-Technical Barriers

Non-technical barriers are hurdles put in front of emergent technologies that will slow or even prevent their maturity. Lack of knowledge and understanding can prevent local authorities from giving permits for the installation of prototypes. Uncertainties around power generation in terms of power quality and availability can hold up a permit to generate electricity. Lack of knowledge on device behaviour predictions can create difficulties in financing a project. Difficulties in comparing different systems can give concern to power distributors on which systems best fits their needs. Unidentified environmental impacts before deployment can be a barrier to technology development. These concerns are of interest to all the stakeholders in a technology and as such are topics for common research activities. The research areas that will address common barriers can be classified as resource assessments, energy production forecasting, simulation tools, test and measurement standards and the environmental impact.

Resource potential assessment

Resource potential assessment needs to be refined and extended. Resource assessment provides information about how much energy is available and where it is accessible and is the first step in enabling decision-making for device developers, deployment project sponsors, and policymakers. Past estimates, in 1992 for wave and tidal current technologies and in 1996 as a wave energy resource atlas for Europe, have given numbers for offshore applications and according to the available technologies for measurement and exploitation. In addition to previous knowledge, these estimates have allowed developers to promote devices like LIMPET, PICO and SEAFLOW. A number of developments during the past decade would suggest that updated resource assessments are now required, including:

> Measurement technologies have improved and knowledge in oceanography has deepened.
> New ocean energy concepts and devices have been also developed that opened new exploitation possibility.

- Earth observation satellites have dramatically improved, enabling wave height and physical proper ties to be measured with increased precision.
- Weather forecasting and climate change models have also improved that could simulate patterns in wave generation and in currents behaviours.

New ocean energy concepts and devices have been developed that have opened new exploitation possibility. They require more detailed knowledge of the waves and tidal currents. They need access to a database or an atlas showing energy available and including the following:

- Wave energy or current speed depending of the device,
- Grid connection available,
- Harbour facilities available,
- Presence of natural reserves or of restricted areas,
- Status of the access to the site.

A new methodology may need to be defined to adapt to the available current databases. New expertise may be needed to complement an existing knowledge focused on energy. Such databases have started to be compiled at national level and should be developed on a regional basis. The scope and the universality of the assessment will be limited only by the ambition and the resources put together.

Energy production forecasting and design simulation tools

Energy production forecasting and design simulation tools are closely related and needed by device developers, electricity system operators and investors. While a device developer knows intuitively how his concept should behave in real sea conditions, he needs nevertheless to provide data on energy production to relevant stakeholders that will predict with confidence the device interaction with the marine environment.

Simulation and predictive tools should be designed and certified so that investors, electricity suppliers, electricity system operators and insurance brokers can take reasonable decisions.

Test and measurement standards

Test and measurement standards are essential for the future deployment of and prospects for ocean energy systems. These standards are complementary to the previous topic. They will provide to all the stakeholders a means by which comparisons between systems can be made and decisions on which concept best fits a particular development to be taken. Such standards need to be valid across technologies and independent of site testing, however will need to be specific for particular resource types, for instance wave will require a different set of standards from tidal. The standards will need to be clearly defined for lay-persons to understand and choose the system best suited to their needs.

Environmental impacts

Environmental impacts, contrary to common understanding, are not limited to the impact of systems on the environment, but also from the environment to the systems. This duality is very specific to ocean energy systems where the marine environment has a strong influence on the device design and performance (a similar impact is seen in shipbuilding design). As was the case in the previous topic, different technology areas will require specific technological solutions. Nevertheless the study of these impacts could be undertaken in a global analysis. For example, impacts from the marine environment can be marine growth, like algae and shells, or seabirds nesting or impact of corrosion or sedimentation flow on the devices. On the other hand, impacts to the marine environment could be oil leakage from engines or noise from power take-off systems or debris from sunken devices. Both aspects are intertwined and will have an impact on system design.

Arrays or farms of Ocean Energy Systems

The unit size of a wave energy device, no more than a few megawatts, will lead to the consideration of operating in arrays of systems or farms in order to achieve economies of scale, as is the case for wind energy. The impact of unit interaction on power generation efficiency and quality, the impact of large-scale energy extraction on the environment and the potential benefits of scale economies should be addressed and documented.

Dual-purpose plants

Dual-purpose ocean energy plants are a longer term means to decrease costs and improve the economic viability of ocean energy systems. The incorporation of a wave concept into a breakwater will reduce costs by using the wave breaker as a supporting structure for the wave energy device (and possibly requiring less material for the breakwater). The incorporation of a wave concept with an offshore wind turbine could reduce cost through the use of the same high power cable to the shore and increased production capacity on a typical site. Preliminary technical and economic assessments, followed with scaled prototype testing, are needed to further these innovative crosscutting concepts.

Technical Barriers

Technical barriers are technical hurdles that need to be solved by research activities to bring a concept to its full potential. Every concept has its own list of specific technical barriers. Nevertheless, there are common denominators among similar types of concepts. For simplification these barriers will be categorized in to technology areas: wave, tidal stream, OTEC and salinity gradient. Some cross-cutting aspects will be also highlighted.

5.2.1 | Wave energy systems

Wave energy systems are divided into two main categories, fixed devices and floating devices.

A fixed device has a solid foundation. This foundation can be incorporated either in the coastline, in a breakwater structure, or on an offshore platform that is fixed on the seafloor. Nowadays the most advanced concepts are installed on the shoreline. A floating device is a completely floating structure, like a ship, that can be linked to the shore via a high voltage power cable. Such a device is kept in position either with a mooring system or with motors.

Within each group there is a range of wave energy technologies under development and because their specificities are so wide ranging, defining R&D needs would lead to a large list of small details important for each concept. However, in the summary the common concerns and needs, like wave behaviour and hydrodynamics of wave absorption, structure and hull design method, mooring, power take-off systems and deployment methods are briefly described below.

Wave behaviour and hydrodynamics of wave absorption

Basic knowledge on subjects, such as wave behaviour and hydrodynamics of wave absorption, is needed to allow engineers to design the best device for a specific concept. For example, only deep water wave climate is generally known and available, although in some countries mapping of the near shore resource has already been carried out. Coastal wave forecasting and behaviour are needed because even for offshore devices that will be in general installed in 50m+ water depth where bottom effects are in general not strong, the effect of shelter by the coastline and the presence of islands is important. Hydrodynamics of wave absorption models need to be improved in order to include non-linear effects that are known to be important.

Design with confidence in reliability and survivability.

The offshore oil exploration industry has a strong knowledge base that can provide information useful for the development of offshore floating prototypes and reduce risks during early sea trials. The transfer of knowledge from existing offshore industries is needed.

Hull design must exhibit seaworthiness. While some devices may appear to be similar to ocean vessels, a wave energy device is not a ship. Therefore, there is a need to develop a common set of parameters and requirements specific to wave energy to which every device should adhere in order to provide confidence of reliability and survivability.

Generic mooring techniques

As a means to keep the system safely in one position whatever the weather conditions, mooring is an important element of an offshore wave device. Shipbuilding and offshore industries have a strong knowledge base in this domain However, wave energy systems will typically be installed in deep water, from 50m to 400m, and face strong wave climates most of the time. These are not the usual conditions faced by a moored ship or offshore platform. Each device mooring will require a complete and independent design, but a generic investigation in mooring techniques will allow the current codes of practices and engineering standards to be expanded to include wave energy systems' specific requirements.

Power take-off systems

Power take-off systems need a strong research effort. As they are converting the incoming energy into electricity, they are the most important part of an ocean energy plant. These systems can be based on hydrodynamic, mechanical or even magnetic conversion concepts. For example, air turbines are commonly used in oscillating water columns and their performance can still be improved and cost reduced. These can be done through new turbine concept development, blade optimisation, and variable-pitch control systems. Noise from the airflow needs to be reduced efficiently with low influence on the turbine performance. Each power take-off systems requires similar research on performance optimisation, seaworthiness and cost reduction.

Deployment methodology & decommissioning

The deployment methodology needs to be reliable, replicable and cost effective. The reliability of the method will provide confidence in the installation process and therefore lower risk-based costs such as insurance premiums. A method that is replicable for many sites and conditions will also reduce installation cost and increase confidence. Furthermore, decommissioning, the reverse process of deployment, should also be addressed. The deployment method is closely related to the supporting structure of the wave energy systems, which should be designed to take into account these requirements and to give best performance in all sea climates. The three phases of operation requiring access, deployment, maintenance and repair, and decommissioning, will have different technical requirements and each will impact on the total system cost.

Tidal Stream Current Systems | 5.2.2

Research and development needs for tidal stream current systems are closely related to the problems faced by present developed devices. Nowadays, these systems are based on the concept of underwater turbines converting energy from the flowing water into electrical power. These systems follow principles similar as wind turbines in the atmosphere. In the same pattern the turbines can have a horizontal rotating axis or a vertical rotating axis. They could even use reciprocating foils. So far development has not shown which system is best.

Transfer of knowledge to an underwater environment

Transfer of knowledge is an important element of research for tidal stream current devices. Horizontal rotating axis turbines will benefit from development made by the wind industry. Experience gained in ship and submarine propellers should be also taken into account. In thus way, the research effort could focus on adapting the technology to an underwater environment.

Typical research needs are also divided into basic knowledge, like water stream flow pattern and cavitations, supporting structure design, turbines, foundations and deployment method.

Basic knowledge of the current speed along the water column

Basic knowledge is needed to allow engineers to produce the best design. MW size tidal stream current turbines will operate at depth below 20m with rotor diameter around 12m for horizontal axis systems. Maritime charts provide only surface current speed. Knowledge of the current speed along the water column is essential to choose the correct turbine and rotor size and to design the supporting structure to resist stresses and vibrations. This information is also important during the installation phase. Knowledge of the water flow patterns and reaction to the turbines is important for example to assess the impact on the sedimentation patterns. The development of adequate measuring instrumentation is linked to these research activities.

Structure must be water tight

Contrary to wave energy devices, the supporting structure of a tidal stream current system has very restrictive requirements that influence the design of the turbine, the installation procedure and the operation and maintenance demands. Above all the structure must be water tight. It should then allow easy access for maintenance and facilitate the deployment process. Therefore, seals should support pressures in 10 to 20 meter water depths, support pressure changes due to tidal variation and resist the abrasive properties of sea-water and sediment flow. In addition, turbines must be reliable to limit access requirements, reducing operation and maintenance costs.

Cost, efficiency, reliability and maintenance

The research effort on the turbine stator and rotor should focus on cost efficiency, reliability and ease of maintenance. Both components should be in materials designed to resist marine environments. Special attention should be given to bearings to ensure that they function safely and reliably in the marine environment. Control systems for turbine speed and rotor blade pitch will also be important to maximise power output.

Foundation and installation methods

Foundation and installation methods are critical and research is needed to make them safe, easily replicable and cost effective. Tidal current systems themselves require very stringent reliability parameters. Firstly, systems will be installed in currents with speed between 2m/s, 7.2km/h, and 4m/s, 14.4km/h; due to the density of water, the equivalence for wind speed will be between around 70km/h and 140km/h. Secondly, while there will be tidal variation, these current speed levels are always present. The combination of these two points requires that tidal stream system foundations are robust and that deployment methods are safe for the equipment and the workforce. Several solutions are being developed and research actions are needed.

Being a new technological development in the world of ocean energy systems, salinity gradient systems need to overcome several hurdles. The main difficulty is the development of functioning and efficient membranes able to generate sufficient energy to make an energy system competitive. The complementary development needed is system integration into a power generation plant. The EC project, SALINITY POWER, estimates that the first commercial power plants would need membranes capable of power production of at least 6W/m2 and could have a size of around 10MWe, corresponding to around 1,700,000m2 of membranes. Future developments would lead to industrial scale production at reduced costs.

Development of functioning and efficient membranes

The scope of research in membrane development should cover performance improvement, manufacturing potential and cost reductions. A membrane needs to "generate" power, to be resistant to biological and chemical contaminations, and to be strong physically and enduring. Best performing membranes have been measured at 1.5W/m2. However, the same membranes have a power potential of 5W/m2. Basic research and technical development are needed to fulfil this potential and to increase it. The manufacturing potential of a membrane is the capacity for large scale production without loss of performance. A high power potential can be obtained relatively easily on a centimetre scale sample, but to keep the same performance at much larger dimensions requires further research.

5.2.4 | Ocean Thermal Energy Conversion

Research needs are closely linked to the nature of ocean thermal energy conversion (OTEC) systems. Many advances were made during the past decades, but obstacles to the full exploitation of ocean thermal energy remain. Three main research areas can be identified: thermal cycles, environmental influence and floating applications.

Thermal cycle

OTEC systems use small temperature differential cycles, the control or which needs to be maintained in order to keep high conversion efficiency. Therefore, research actions should address the development of power technologies, integrated systems and control strategies adapted to the marine environment and to ocean thermal applications.

Influence of the environment

The environmental impacts of OTEC systems need to be addressed. The marine environment, e.g. corrosion and marine growth, have a direct impact on the materials and on the equipment used. Research focused on reducing these impacts on the OTEC systems should also aim to reduce the systems' influence on marine ecosystems.

Floating Systems

Applications using OTEC on floating structures offer a wider scope for deployment. These applications can range from the use of the produced energy in onsite ore smelting to plankton feeds. The wide range of possible uses will require research to solve the particular problems associated with each. Nevertheless, the requirement for floating structures will need to resolve issues similar to offshore wave and tidal structures, such as mooring and survivability. In addition, the mechanical resistance and stability of an OTEC installation, deep water piping and positioning, should also be addressed with the transport of energy from the production site to the site of energy use.

5.3 Costs and benefits of additional R&D

Over the last twenty years, ocean energy developers received little R&D funding. For example, European Communities Framework Programme financed projects over that period for a total contribution of 26M€, equivalent to only 10% of the funding contributed towards photovoltaic projects.

Increasing R&D funds will speed up the rate of development. The effort and finance put forward in the United Kingdom is already showing an increase in technical progress. Several concepts are envisaging full scale demonstration prototypes around the British coast.

Additional R&D funding is critical to advancing the development of ocean energy systems. Ocean energy technologies must solve two major problems concurrently: proving the energy conversion potential and overcoming a very high technical risk from a harsh environment. No other energy technology has had to face such demands. When deploying their prototype, device developers are confronted with the possibility of losing five years of development and investment in few hours time.. Furthermore, the majority of the developers are SMEs for whom such a loss can be overwhelming. Additional R&D funding would help to mitigate the substantial technical risk faced by device developers daring to harness the energy of the marine environment.

6 NATIONAL POLICIES

In the year 2003 the ExCo decided to start including a section on National Activities in its Annual Report, describing the ocean energy activities in the Member Countries, national policies, research, demonstration and (pre-) commercial activities. In 2004 this activity was also extended to Observers among which Italy, United States of America and Australia sent contributions. Standard surveys on three topics: (i) national policy, ii) organizations for research, development and dissemination of ocean energy and iii) companies active in the development and commercialization of ocean energy technologies, are sent to each ExCo member or country observer. They are asked to provide as much information as possible on the surveys. It should be noted that the amount of information available to each member or observer is not consistent. This section presents a summary of the information concerning national policy provided by participants in this activity.

6.1 European Commission

Organisations supporting ocean energy

> Directorate General Research
  http://europa.eu.int/comm/research/energy/index_en.htm

> Directorate General Transport and Energy
  http://europa.eu.int/comm/dgs/energy_transport/index_en.html

Targets for renewable energy

By 2010 for all Member States:

- > 12% of the gross energy consumption of the European Union
- > 22% of the electricity generated in the European Union

Targets for ocean energy

White Paper [COM(97)599]:

> 1GWe of installed capacity for Concentrated Solar Thermal, Ocean Energy Systems [“wave and tidal” in the text] and enhanced geothermal systems [“hot dry rock” in the text] by 2010.

Important policy initiatives bearing on the contribution that ocean power can make to renewable energy supply

1. Communication “Energy for the Future: Renewable Sources of Energy” a White Paper for a Commu nity Strategy and Action Plan, COM(97)599 final
2. Energy for the Future: Renewable Sources of Energy (Community Strategy and Action Plan) - Cam paign for Take-Off, SEC(99)504
3. Directive 2001/77/EC of the European Parliament and of the Council, OJEC L238/33 27.10.2001

Undergoing ocean energy projects supported by the EC

Title	CA-OE	Wave Dragon 1:4.5	Salinity Power
Coordinating Organisation	Ramboll	Spok Aps	Statkraft SF
Country	Denmark	Denmark	Norway
Type of project (instrument)	FP6 Coordination Action	FP5	FP5
Start	01-10-2004	01-10-2002	01-11-2001
Duration	36	33	36
EC Contribution	1.500.000 €	1.532.999 €	1.808.752 €

6.2 Canada

ORGANISATIONS SUPPORTING OCEAN ENERGY	WEBSITE
Government of Canada – Federal Ocean Energy Working Group (FOEWG)	
British Columbia Ministry of Energy and Mines	www.gov.bc.ca/em
Nova Scotia Government	
New Brunswick Ministry of Energy	

Following publication of Ocean renewable Energy Group's (OREG)) strategic framework for the development of Canada's ocean energy sector, Natural Resources Canada has mobilized an interdepartmental initiative of energy, fisheries, environment, industry departments, economic development agencies, and national laboratories. This group is using existing government resources and programmes to launch projects such an Ocean Energy Atlas, an environmental scan for ocean energy development, a technology screening and an analysis of the industry that will mobilize into the Canadian Ocean Power Sector. For further information on the Federal Ocean Energy Working Group (FOEWG), please contact Marielle Nobert (Marielle.nobert@NRCan.gc.ca).

The goals of the Federal Ocean Energy Working Group (FOEWG) are:

- To foster technological development and develop Canadian capacity,
- Coordinate federal S&T efforts and interests in ocean energy,
- Develop synergies and partnerships between federal departments and agencies,
- Ensure that projects and initiatives are complementary to avoid duplications and overlaps,
- Encourage a sustained momentum in the progress on ocean energy through regular meetings and communications, and
- Inform government leadership on Canadian opportunities and initiatives in ocean energy.

Natural Resources Canada will be leading reviews of energy funding programmes and incentive programmes in 2005/6 and is addressing the ocean energy option in development of a renewable Energy Strategy in 2005.

The Ocean Energy sector has been identified as a promising emerging technology, and as a priority for review and action by four coastal provinces of the Canadian Council of Energy ministers.

In late 2004, the British Columbia Premier's Technology Council developed a vision for British Columbia as a source of alternate electricity, power and alternate energy technology and projects. An Alternate Energy and Power Technology Task Force is expected to deliver an action plan to realize these opportunities in 2005. Ocean energy has been clearly identified as a strategic opportunity for the region.

Targets for renewable energy

Wind Power Production Incentive (WPPI) will provide financial support for the installation of 1,000 megawatts of new capacity over the next five years (2002-2007).

In December 1997, NRCan began purchasing green power from ENMAX, Calgary's electric system. The 10-year agreement with ENMAX is for the production of 10,000 megawatt hours of green power annually for NRCan's Alberta facilities. Environment Canada also signed an agreement with ENMAX for 2000 megawatt hours of green power for their electricity requirements in Alberta. Together, the NRCan and Environment Canada agreements will displace more than 10,000 tonnes of CO2 annually.

Under Action Plan 2000 on Climate Change, it is expected that the federal government will purchase an additional 400,000 megawatt hours or so of electricity from Emerging Renewable Energy Sources meaning wind power, sun, water, biomass and the earth. Assuming a continued focus on the displacement of high-carbon electricity, this 400,000 megawatt hours will come from several provinces, particularly Nova Scotia, Ontario and New Brunswick, with additional purchases in Alberta. These purchases will result in a further reduction in greenhouse gas emissions of about 200,000 tonnes annually.

Electricity distributors in British Columbia shall pursue a voluntary goal to acquire 50% of new supply from BC Clean Electricity between 2002 and 2012.

Targets for ocean energy: No specific national target for ocean energy.

Important policy initiatives bearing on the contribution that ocean power can make to renewable energy supply

There is no specific program or policy on ocean energy development. However, some programs could support R&D and demonstration projects related to ocean energy. Examples include:

> Climate Change Technology and Innovation Initiative: Created in 2003 by the federal government. This 5-year program will support collaborative projects with partners in five strategic areas, including decentralized energy production. The objective of this program is to accelerate research, development and demonstration of longer term technologies to achieve GHG reductions. For further information on the R&D component of this program, please contact Milena Sejnoha (msejnoha@nrcan.gc.ca). For additional information on the demonstration component, please visit the Technology Early Action Measures (TEAM) website http://www.climatechange.gc.ca/english/actions/action_fund/techno.shtml)

> Sustainable Development Technology Canada: an arm's length foundation which was developed through a national government initiative to foster the rapid development, demonstration and pre-commercialization of technological solutions, which address climate change and air quality (http://www.sdtc.ca).

6.3 Denmark

ORGANISATIONS SUPPORTING OCEAN ENERGY	WEBSITE
Danish Energy Authority - DEA	www.ens.dk
Energinet.dk	www.energinet.dk

Targets for renewable energy

> 29 % of electricity consumption from RES in 2010 according to the EU Directive – renewable energy. 1,4 mio tonnes of biomass (straw & wood) to be used for combined heat & power production in 2005.

Targets for ocean energy: No quantified targets.

Important policy initiatives bearing on the contribution that ocean power can make to renewable energy supply

> Through the National Energy Research Progamme, DEA supports R&D within new energy technologies - including wave energy. However, there are no fixed amounts of funding set aside from the programme dedicated to specific technology areas.– that includes waveenergy. The best projects will be selected for support based on a set of horizontal criteria

> Energinet.dk supports R&D in deployment of environmentally friendly electricity production technologies. Wave energy is part of this. However, there are no funds set aside from the fund dedicated to wave energy.

> The DEA together with Energinet.dk are in the process of preparing a strategy for R&D within wave energy technology in Denmark.

Programmes that support other RE technologies but are not available to ocean energy

> The research program is for deployment of environmentally friendly electricity production technologies, e.g. biomass, wind power, solar cells, fuel cells, hydrogen, liquid biofuels.

ORGANISATIONS SUPPORTING OCEAN ENERGY	WEBSITE
Sustainable Energy Ireland	www.sei.ie
Marine Institute	www.marine.ie
Enterprise Ireland	www.enterprise-ireland.com
Department of Communications, Marine and Natural Resources	www.dcmnr.gov.ie

Targets for renewable energy

> RES-E Directive target of 13.2% electricity consumption from renewable energy sourced electricity by 2010.

> Capacity target of 500 MW additional RES-E generating capacity by 2005.

Targets for ocean energy: No specific targets.

Important policy initiatives bearing on the contribution that ocean power can make to renewable energy supply

The Marine Institute and Sustainable Energy Ireland have been working jointly to prepare an enterprise driven ocean energy strategy proposal for Ireland. These two agencies have prepared and commissioned a consultation on strategy options, resource studies on the ocean wave resource and the tidal and marine current resource, a development protocol, and a study on the economic benefits of ocean energy development in Ireland. These documents will form the basis for a government decision on an appropriate strategy for the country in regard to the ocean energy resources.

Programmes that support other RE technologies but are not available to ocean energy

There have been six rounds of competitive tender competition for guaranteed power purchase agreements for a limited capacity of onshore wind, offshore wind, small hydro and various bio-energy resources. Ocean energy was included in AER III however the contract offer, won by Wavegen, was not taken up, due to objections from the European Commission under state aid rules.

6.5 Italy

ORGANISATIONS SUPPORTING OCEAN ENERGY	WEBSITE
Ministry of Foreign Affairs	www.esteri.it/ita/index.asp
Region Sicilia	www.regione.sicilia.it/

Important policy initiative bearing on the contribution that ocean power can make to renewable energy supply:

Cooperation with UNIDO

Figure 7 | Tidal marine currents project - KOBOLD TURBINE (Ponte di Archimede)

ORGANISATIONS SUPPORTING OCEAN ENERGY	WEBSITE
INETI	www.ineti.pt
Instituto Superior Técnico	www.ist.utl.pt
Wave Energy Centre	www.wave-energy-centre.org

Targets for renewable energy

Target 39% of the electricity consumption from RES in 2010 according to the EU Directive – Renewable Energy

Target of 9680 MW additional RES – electricity generating capacity by 2010 .

Targets for ocean energy

Capacity target of 50 MW of wave energy by 2010

Important policy initiatives bearing on the contribution that ocean power can make to renewable energy supply

The policy initiatives for ocean energy are common to other RES:

> National R&D Programme, Ministry of Science, Higher Education and Technology
> Innovation Programme, Ministry of Economy and Innovation
> Regulation of grid connection of electricity production from independent producers
> Permitting and power purchase agreement (special tariffs technology differentiated)

Programmes that support other RE technologies but are not available to ocean energy

Financial support for production of electricity from RES, rational use of energy and conversion of consumption to natural gas

Figure 8 | The AWS device during the submergence process offshore Portugal (Teamwork Technology)

6.7 United Kingdom

ORGANISATION SUPPORTING OCEAN ENERGY	WEBSITE
Department of Trade & Industry	www.dti.gov.uk
Carbon Trust	www.thecarbontrust.org.uk
Engineering and Physical Sciences Research Council	www.epsrc.ac.uk

Targets for renewable energy

> 10% of electricity by 2010

> aspiration of 20% by 2020

> also target to reduce carbon dioxide emissions by some 60% by around 2050

Targets for ocean energy: No formal target

Important policy initiatives bearing on the contribution that ocean power can make to renewable energy supply

> Renewables Obligation

> Offshore renewables consents framework

> European Marine Energy Centre

> Marine Renewables Deployment Fund

> DTI Technology Programme

> Supergen Marine

The UK set out its Energy Policy in the 2003 Energy White Paper. "Our energy future – creating a low carbon economy " defines a long-term strategic vision for energy policy combining our environmental, security of supply, competitiveness and social goals. It builds on the (External) Performance and Innovation Unit's Energy Review , published in February 2002, and on other reports which have looked at major areas of energy policy.

The implementation of the White Paper is being taken forward via the Sustainable Energy Policy Network (SEPN)

Because energy requires very long-term investment we look ahead to 2050 to set the overall context. We set out the challenges we face on the environment, the decline of our indigenous energy supplies and the need to update our energy infrastructure and the policies we need to pursue over the next twenty years and beyond to meet these challenges.

As we address these three challenges, we will have four goals for our energy policy:

> to put ourselves on a path to cut the UK's carbon dioxide emissions - the main contributor to global warming - by some 60% by about 2050 with real progress by 2020;

> to maintain the reliability of energy supplies;

> to promote competitive markets in the UK and beyond, helping to raise the rate of sustainable economic growth and to improve our productivity; and

> to ensure that every home is adequately and affordably heated.

The UK has a target to supply at least 10% of power from renewables by 2010 and an aspiration to double this to 20% by 2020. This is a part of the Government's wider Climate Change Programme, which details how the UK plans to deliver its Kyoto target to cut its greenhouse gas emissions by 12.5%, and move towards its domestic goal to cut carbon dioxide emissions by 20% below 1990 levels by 2010.

The country has a diverse range of sustainable energy resources to fuel the rapid expansion of renewable energy production needed to meet this commitment. Market growth has been driven since 2002 by the Renewables Obligation, a legal obligation on all licensed electricity suppliers to source an increasing proportion of their power sales from renewables, thus creating a commercial opportunity for cost competitive renewable energy projects.

The UK is a world leader in the development of new and renewable energy and energy efficient systems and has benefited from the commercial experiences gained under the Renewables Obligation.

Marine Renewables

As an Island nation, the UK is blessed with extensive marine energy resources, which have the potential in the longer term to meet a considerable proportion of the Nation's power demands at a competitive cost. Although the technologies are not mature, the Government is committed to support these emerging technologies through a number of schemes.

The UK is also currently developing a consenting regime for deployment of pre-commercial scale projects in a way which best manages potential impacts and enables monitoring and assessment of the actual impact of these new technologies on the marine environment and other users of the sea.

Since 1999, the UK has committed approx. £25m on pre-competitive R&D on wave and tidal stream devices, £2.6m for support of the Supergen strategic fundamental research programme, and £5m for EMEC wave and tidal testing facilities. It has been determined that there is need for funding the gap between R&D and pre-commercial deployment in the marine area. Proposed UK policy to address this gap is the Marine Renewables Deployment Fund. The centrepiece of the Fund is a proposed £42m demonstration fund that will have two envisaged strands: Capital support at 25% of the capital cost of initial deployment excluding grid connection costs, and revenue support in addition to ROCs at £100/MWh for a maximum of seven years from commissioning .

The Carbon Trust's Marine Energy Challenge, a technology acceleration programme involving marine energy device developers and specialist engineering consultants. Launched in January 2004, the programme has a budget of £2.94M (approximately 4.3M) and is accelerating development of eight wave energy devices (selected on the basis of a competitive tender advertised in OJEU). In addition, Shoreline/Near-shore Oscillating Water Columns (OWCs) projects are being conducted, existing engineering codes/standards are being interpreted for offshore wave energy devices, and the prospects for development of tidal stream energy are assessed.

> Support for industrial R&D of other marine energy generation systems through the Carbon Trust's Research, Development and Demonstration programme.

> A venture capital investment of over £1.5M (approximately 2.1M) in Ocean Power Delivery Ltd., a UK developer of an offshore wave energy device.

> Support for EMEC (the European Marine Energy Centre) in Orkney - including its proposed expansion to accommodate testing of tidal stream devices.

Figure 9 | The Pelamis (Ocean Power Delivery Ltd)

6.8 United States of America

Figure 10 | PowerBuoy (Ocean Power Technologies)

ORGANISATIONS SUPPORTING OCEAN ENERGY	WEBSITE
U.S. Dept. of Energy Wind and Hydropower Technologies Program	http://www.eere.energy.gov/windandhydro/
Electric Power Research Institute, Electricity Innovation Institute	http://www.epri.com/D2004/e2i.aspx
Ocean Energy Council	http://www.oceanenergycouncil.org/
Alexandria Research Institute	http://www.ari.vt.edu/

Targets for renewable energy

No targets are set by the Federal government for renewable energy deployments in the U.S.; instead, cost-of-energy, efficiency, and criteria-based deployment-support targets have been set for individual technologies by their respective programs. In its current strategic plan, the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE) describes its federal role in fostering high-risk, high-value R&D that is both “critical to the Nation’s energy future and would not be sufficiently conducted by the private sector.” EERE’s nine strategic priorities are to: dramatically reduce, or even end, dependence on foreign oil; reduce the burden of energy prices on the disadvantaged; increase the viability and deployment of renewable energy technologies; increase the reliability and efficiency of electricity generation, delivery, and use; increase the energy efficiency of buildings and appliances; increase the energy efficiency of industry; spur the creation of a domestic bioindustry; lead by example through government’s own actions; and change the way EERE does business.

Targets for ocean energy

The U.S. DOE Wind and Hydropower Technologies Program is developing a target for the future cost of offshore wind energy. Federal targets are currently not set for other forms of ocean-based energy; however, several U.S. manufacturers have expressed significant development objectives.

Important policy initiatives bearing on the contribution that ocean power can make to renewable energy supply

The President's National Energy Policy Plan (May 2001) sets forth several policy recommendations that generally encourage increasing energy supplies, including renewables such as ocean energy, accelerate protection and improvement of the environment, and increase energy security. At the state level, recently-enacted renewable portfolio standards in several states, and supportive renewable energy tax polices may be applicable to ocean energy development. Additionally, green power certificates offered at the state and utility level may play an important role in attracting future ocean energy development.

Programmes that support other RE technologies but are not available to ocean energy

DOE EERE currently operates four other renewable energy technology and deployment support programs (wind and hydropower, solar, biomass, and geothermal); currently there is no distinct Federal ocean energy research and development program. Similarly, at the state level, R&D support for RE may be limited to selected technologies.

Figure 11 | Tidal marine currents project
OPEN-CENTER TURBINE (Florida Hydro, Inc.)

EXCO MEMBERS AND ALTERNATES

CHAIR 2004 (VICE-CHAIR 2005)

Dr. TERESA PONTES
INETI – DER
ESTRADA DO PAÇO DO LUMIAR
1649-038 LISBOA, PORTUGAL
TEL:+351 21 7127201
FAX:+351 21 7127195
EMAIL: TERESA.PONTES@INETI.PT

VICE-CHAIR 2004 (CHAIR 2005)

MRS. KATRINA POLASKI
SUSTAINABLE ENERGY IRELAND
GLASNEVIN
DUBLIN 9
EIRE
TEL: + 353 (0)18082385
FAX:+ 353 (0)18082244
EMAIL: KATRINA.POLASKI@SEI.IE

SECRETARY

DR. ANA BRITO E MELO
WAVE ENERGY CENTRE
AV. MANUEL DA MAIA, 36 – R/C DIRTO
1000-201 LISBOA
TEL: +351 21 8482655
FAX:+351 21 8417398
EMAIL1: IEA.OES@WAVE-ENERGY-CENTRE.ORG
EMAIL2: ANA@WAVE-ENERGY-CENTRE.ORG

CANADA

DELEGATE MEMBER

DR. GOURI BHUYAN
POWERTECH LABS INC.
12388-88TH AVE
SURREY, BC, V3W 7R7
CANADA
TEL: 1 604 590 7407
FAX: 1 604 590 5347
EMAIL:GOURI.BHUYAN@POWERTECHLABS.COM

DENMARK

DELEGATE MEMBER

MR. JAN BÜNGER
DANISH ENERGY AUTHORITY
AMALIEGADE 44
COPENHAGEN
DENMARK, 1456
TEL: + 45 33 927589
FAX:+ 45 33 114743
EMAIL: JBU@ENS.DK

ALTERNATE MEMBER

DR. KIM NIELSEN
RAMBØLL
TEKNIKERBYEN 31
VIRUM
DENMARK, 2830
TEL: +45 45 98 8441
FAX:+45 45 98 8797
EMAIL: KIN@RAMBOLL.DK

EXCO MEMBERS AND ALTERNATES

EUROPEAN COMMISSION

DELEGATE MEMBER (2004)
DR. PHILIPPE SCHILD
RESEARCH DIRECTORATE-GENERAL
DIRECTORATE J: ENERGY
UNIT: J3, NEW AND RENEWABLE ENERGY SOURCES
VISITING ADDRESS:
RUE DU CHAMP DE MARS 21, B – 1050 BRUSSELS
MAIL ADDRESS:
CDMA 5/141, B- 1049 BRUSSELS
TEL: +32-2-29.62225
FAX: +32-2-29.94.991
E-MAIL: PHILIPPE.SCHILD@CEC.EU.INT

DELEGATE MEMBER (2005)
DR. KOMNINOS DIAMANTARAS
RESEARCH DIRECTORATE-GENERAL
DIRECTORATE J: ENERGY
UNIT: J3, NEW AND RENEWABLE ENERGY SOURCES
VISITING ADDRESS:
RUE DU CHAMP DE MARS 21, B – 1050 BRUSSELS
MAIL ADDRESS:
CDMA 5/177, B- 1049 BRUSSELS
TEL: +32-2-29.55.851, +32-2-2950036 (SECR)
FAX: +32-2-29.94.991 (NEW)
E-MAIL:KOMNINOS.DIAMANTARAS@CEC.EU.INT

IRELAND

DELEGATE MEMBER
MRS. KATRINA POLASKI
SUSTAINABLE ENERGY IRELAND
GLASNEVIN
DUBLIN 9
IRELAND
TEL: + 353 (0)18082385
FAX:+ 353 (0)18082244
EMAIL: KATRINA.POLASKI@SEI.IE

ALTERNATE MEMBER
DR. TONY LEWIS
HYDRAULICS AND MARITIME RESEARCH CENTRE
UNIVERSITY COLLEGE CORK
CORK
IRELAND
TEL: +353 21 4902033
FAX: +353 21 4321003
E-MAIL: T.LEWIS@UCC.IE

PORTUGAL

DELEGATE MEMBER
DR. TERESA PONTES
DEPARTMENT OF RENEWABLE ENERGIES
INETI
ESTRADA DO PAÇO DO LUMIAR
1649-038 LISBOA
PORTUGAL
TEL: +351 21 7127195
FAX:+351 21 7127195
EMAIL: TERESA.PONTES@INETI.PT

ALTERNATE MEMBER
PROF. ANTÓNIO FALCÃO
DEPARTEMENT OF MECHANICAL ENGINEERING
INSTITUTO SUPERIOR TÉCNICO
AV. ROVISCO PAIS
1049-001 LISBOA, PORTUGAL
TEL: +351 21 841 7273
FAX:+351 21 841 7398
EMAIL: FALCAO@HIDRO1.IST.UTL.PT

UNITED KINGDOM

DELEGATE MEMBER
MR. GARY SHANAHAN
DEPT. OF TRADE AND INDUSTRY
1 VICTORIA STREET
LONDON SW1H OET,
UNIT KINGDOM
TEL: +44 20 7215 6481
FAX:+44 20 7215 2674
EMAIL: GARY.SHANAHAN@DTI.GSI.GOV.UK