INTERNACIONAL ENERGY AGENCY

ANNUAL REPORT > 2003

IMPLEMENTING AGREEMENT ON OCEAN ENERGY SYSTEMS

IEA | OES

Ocean Energy Systems

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

FOREWORD

After almost thirty years of research and technology development on the utilization of wave energy and marine current energy, it is recognized that we are getting close to the exploitation phase of these renewable ocean energy resources.

The proposed wave energy devices are based on a wide range of concepts and can be classified according to location. *First generation* devices, which use more conventional technology, are fixed devices located at the shoreline where access is easier but the resource is lower due to the energy dissipation in shallow waters, and the geomorphologic and environmental constraints are high. Of the seven first-generation nearshore prototypes built since 1986, all (except one) are of the Oscillating Water Column (OWC) type. Other two OWC prototypes have been built nearshore (*second generation*). Survivability which is a major issue for wave energy systems has already been proved for OWCs. It should also be mentioned that the second generation OWC incorporated into the harbour of Sakata on the NW coast of Japan has been operating without major maintenance requirements since 1990. Offshore *third generation* devices are in general more complex technologically and in addition require moorings and long electrical cable connection to land. On the other hand, they are less dependent on environmental constraints and exploit the more energetic deep-water resource. They are more appropriate for the large-scale exploitation of wave energy.

The first offshore wave energy prototype was also of the OWC type. The Mighty Whale was launched in 1998 in the bay of Tokyo and tested until 2002. In 2003 the first two third generation grid-connected wave energy devices were deployed. They are the 1:4.5-scaled model of the Wave Dragon being tested in the Baltic Sea and the 750 kW Pelamis prototype whose tests in the Marine Energy Centre in Scotland are planned to start in early 2004. Another system planned to be deployed in 2004 off Portugal is the 2 MW AWS device. Other prototypes are planned to be built in the short-term.

On what concerns marine current devices, in addition to the 130 kW ENERMAR prototype tests that started in 2001 in the Strait of Messina, Italy, in 2003 in the UK the horizontal-axis Seaflow turbine was deployed and the testing of the 150 kW reciprocating wing Stingray was going on.

The review of national activities on wave and marine current energy carried out within this Agreement has revealed that research and development on wave energy and marine current energy continue in 19 countries. Within the six IEA-OES Member Countries almost twenty companies develop and commercialize ocean energy systems. About half of them have already built one or more wave energy or tidal current prototypes or have plans for doing so in the short term. Most of these developers are SMEs that have been able to attract investment by large companies, risk capital, in addition to national and European funding.

The exploitation of these renewable ocean resources will contribute to reduce the risks from fuel supply cost uncertainties, increase the diversity and security of electricity supply and contribute to job creation. Since new technology is required namely for wave energy, a new industry will emerge and new opportunities for existing ones, such as offshore industry, shipbuilding, turbines, hydraulic and electrical equipments, will arise.

WAVE ENERGY SYSTEMS: STATE OF THE ART

by António F. de O. Falcão
Alternate member from Portugal

It can be said that research in wave energy conversion based on adequate scientific background started in the 1970s when the oil crises provoked the exploitation of a range of renewable energy sources, including waves. Based on various energy-extracting methods, a wide variety of wave energy systems has been proposed but only a few full-sized prototypes have been built and deployed in open coastal waters. Most of these are or were located on the shoreline or near shore, and are sometimes named first generation devices. In general these devices stand on the sea bottom or are fixed to a rocky cliff. Shoreline devices have the advantage of easier maintenance and installation and do not require deep-water moorings and long underwater electrical cables. The less energetic wave climate at the shoreline can be partly compensated by natural wave energy concentration due to refraction and/or diffraction (if the device is suitably located for that purpose). The typical first generation device is the oscillating water column (OWC).

Offshore devices (sometimes classified as third generation devices) are basically oscillating bodies, either floating or (more rarely) fully submerged. They exploit the more powerful wave regimes available in deep water (typically more than 40m water depth). Offshore wave energy converters are in general more complex compared with first generation systems. This, together with additional problems associated with mooring, access for maintenance and the need of long underwater electrical cables, has hindered their development, and only recently some systems have reached, or come close to, the full-scale demonstration stage.

The oscillating water column (OWC) device comprises a partly submerged concrete or steel structure, open below the water surface, inside which air is trapped above the water free surface. The oscillating motion of the internal free surface produced by the incident waves makes the air to flow through a turbine that drives an electrical generator.

Full sized OWC prototypes were built and tested under real sea conditions in Norway (in Toftestallen, near Bergen, 1985), Japan (Sakata, 1990), India (Vizhinjam, near Trivandrum, Kerala state, 1990), Portugal (Pico, Azores, 1999 - fig.11), UK (the LIMPET plant in Islay island, Scotland, 2000 - fig. 20). In all these cases, the concrete structure is fixed (bottom-standing or built on rocky sloping wall). The installed power capacity of these prototype OWCs is (or was) in the range 60-500 kW. Smaller shoreline OWC prototypes were built in Islay, UK (about 1990), and recently in China. The so-called Mighty Whale (fig. 6), built in Japan a few years ago, is in fact a floating version of the OWC.

In an OWC plant, the energy conversion chain consists of the following elements: wave to air (in which the structure containing the oscillating water column plays a major role); air turbine; electrical generator (and complementary electrical equipment). The integration of the plant structure into a breakwater has several advantages: the constructional costs are shared, and the access for construction, operation and maintenance of the wave energy plant become much easier. This has been done successfully for the first time in the harbour of Sakata, Japan (in 1990). The option of the 'breakwater OWC' is presently being considered for several situations in Europe.

Several types of air turbines have been proposed for (and in some cases used in) OWCs. The axial-flow Wells turbine, invented in the late 1970s, has the advantage of not requiring rectifying valves. It has been used in almost all prototypes. The most popular alternative to the Wells turbine seems to be the self-rectifying impulse turbine; its rotor is basically identical to the rotor of a conventional single-stage steam turbine of axial-flow impulse type (the classical de Laval turbine).

An Australian company proposes a technology using a parabolic-shaped collector (about 40-metre wide) to concentrate the wave energy upon the OWC structure. The system uses a self-rectifying air turbine that is different from the Wells turbine and the impulse turbine but shares some features of both. The Energetech OWC system (fig. 15) was conceived originally as a bottom-standing structure, but a floating version is presently being considered.

The Pendulor was originally developed in Japan as a shoreline device. Its main element is a hinged rectangular plate facing the waves, whose pendulum-like oscillations drive a high-pressure hydraulic power-take-off system. A floating version of the Pendulor is presently being developed in Japan.

There is a substantial variety of typically offshore wave-energy devices, some of which reached, or are close to, the prototype stage. In most cases, there is a mechanism that extracts energy from the relative oscillating motion between two bodies.

This is the case of the Pelamis (fig. 23), developed in UK, a snake-like slack-moored articulated structure composed of four cylindrical sections linked by hinged joints, and aligned with the wave direction. The wave-induced motion of these joints is resisted by hydraulic rams, which pump high-pressure oil through hydraulic motors driving three electrical generators. Sea trials of a full-sized prototype (120m long, 3.5m diameter, 750 kW rated power) started in the North Sea in March 2004.

The McCabe Wave Pump (fig. 7), developed in Ireland, has conceptual similarities to the Pelamis: it consists of there rectangular steel pontoons hinged together, with hydraulic rams converting their relative motions into useful energy.

The Archimedes Wave Swing (AWS), basically developed in Holland (fig. 19), is a fully-submerged device consisting of an oscillating upper part (the floater) and a bottom-fixed lower part (the basement). The floater is pushed down under a wave crest and moves up under a wave trough. This motion is resisted by a linear electrical motor, with the interior air pressure acting as a spring. A prototype of AWS was built, rated 2 MW (maximum instantaneous power). After unsuccessful trials in 2001 and 2002 to sink it into position off the northern coast of Portugal, a new attempt is planned to take place in May 2004.

The AquaBuOY (fig. 16) combines two concepts developed in Sweden in the 1980s: the IPS buoy and the hose pump. The Aquabuoy consists of a slack-moored vertical-axis buoy, about 7m diameter, whose heave oscillations produce high-pressure water flow by means of a pair of hose pumps. This is converted into electrical energy by a conventional water turbine driving an electrical generator. Plans to build a prototype have been announced.

Another system based on a heaving buoy is the Wavebob, a basically Irish concept that is being developed in Europe.

The Wave Dragon, an offshore floating system mostly developed in Denmark, is based on the overtopping concept rather than on the oscillating body concept (fig. 17). The system consists of a floating slack-moored platform with two long arms acting as wave reflectors to focus the waves towards a ramp. Behind the ramp there is a reservoir where the overtopping water is collected and temporarily stored. The power take-off equipment consists of a series of conventional low-head propeller-type water turbines each one driving an electrical generator. A 1:4.5-scale model, 57m-wide, equipped with 7 turbines, was constructed. The model tests, that included power generation to the grid, started in 2003 off the Danish coast in the North Sea.

Like the Mighty Whale referred to above, the Backward Bent Duct Buoy (BBDB) is a floating version of the OWC that has been object of considerable interest and development, first in Japan, and more recently also in Europe (namely in Ireland).

Unlike in the case of wind energy, the present situation shows a wide variety of wave energy systems, at several stages of development, competing against each other, without it being clear which types will be the final winners.

In the last ten years or so, most of the R&D activity in wave energy has been taking place in Europe, largely due to the financial support and coordination provided by the European Commission and to the positive attitude adopted by some European national governments.

In general, the development, from concept to commercial stage, has been found to be a difficult, slow and expensive process. Although substantial progress has been achieved in the theoretical and numerical modelling of wave energy converters and of their energy conversion chain, model testing in wave basin æ a time-consuming and considerably expensive task - is still essential. The final stage is testing under real sea conditions. In almost every system, optimal wave energy absorption involves some kind of resonance, which implies that the geometry and size of the structure are linked to wavelength. For these reasons, if pilot plants are to be tested in the open sea, they must be full-sized structures. For the same reasons, it is difficult, in the wave energy technology, to follow what was done in the wind turbine industry (namely in Denmark): relatively small machines where developed first, and were subsequently scaled up to larger sizes and powers as the market developed. The high costs of constructing, deploying, maintaining and testing large prototypes under sometimes very harsh environmental conditions, has hindered the development of wave energy systems; in most cases such operations were possible only with substantial financial support from governments (or, in the European case, from the European Commission).

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 basic aims of the IEA are:

> To maintain and improve systems for coping with oil supply disruptions;
> To promote rational energy policies in a global context through cooperative relations with non-Member countries, industry and international organisations;
> To operate a permanent information system on the international oil market;
> To improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use;
> To assist in the integration of environmental and energy policies.

The IEA's programme of International Energy Technology Co-operation includes a mechanism called an "Implementing Agreement". There are currently 42 Implementing Agreements under the IEA International Energy technology Co-operation Framework, grouped in the following domains:

> Fossil Fuels
> **Renewable Energy**
> End-use Technologies
> Information Centres
> Fusion

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

- > Photovoltaic Power Systems (PVPS)
- > SolarPACES (Solar Power and Chemical Energy Systems)
- > Solar Heating and Cooling Programm (SHC)
- > Wind Turbine Systems
- > **Ocean Energy Systems**
- > Hydropower
- > Hydrogen
- > Advanced Fuel Cells

The IEA's international energy technology co-operation activities, in general, including those of the Implementing Agreements are promoted and guided by the IEA Committee on Energy Research and Technology (CERT).

The new "IEA Framework on International Energy Technology Co-operation" that provides the legal mechanism for establishing the commitments of the participants and the management structure to guide work under each Implementing Agreement was approved in 2003. It replaces the previous "IEA Guiding Principles for Co-operation in the Field of Energy Research and Development" (the Guiding Principles). The key issues in this new framework are a change of the policy and procedures for non-Member country and private sector participation. This new rule enables broader participation in the Implementing Agreements, provides more flexibility, as well as legal and administrative clarity for their Executive Committees and for prospective participants.

THE IMPLEMENTING AGREEMENT ON OCEAN ENERGY SYSTEMS 1

Participating Countries 1.1

The IEA-OES was started in 2001 by Denmark, Portugal and UK. Ireland and Japan joined in 2002 and Canada and the European Commission joined in early 2003. During this year the following countries and designated entities are presented in table 1.

The interest in the IEA-OES participation is being encouraged, and prospective members have been invited to attend IEA-OES Executive Committee (ExCo) meetings.

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
JAMSTEC MARINE SCIENCE AND TECHNOLOGY CENTRE	JAPAN
INSTITUTO NACIONAL DE ENGENHARIA E TECNOLOGIA INDUSTRIAL (INETI)	PORTUGAL
DEPARTMENT OF TRADE AND INDUSTRY (DTI)	UNITED KINGDOM

Table 1 | Contracting Parties to the Agreement IEA-OES (status: end 2003)

IEA-OES Objectives 1.2

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 these 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 better prospects for competitive deployment in the short- to medium-term.

The **strategy** of IEA Ocean Energy 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.

1.3 IEA-OES Work Programme

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.

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

Annex I: Review, Exchange and Dissemination of Information on OES

The objective of Task I set on 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 having in view facilitating further development and adoption of cost-effective ocean energy systems through the access to available information.

The participants in this Task update and exchange annually the information on ocean energy systems. Participants further analyse this information to develop joint summary assessments of trends in ocean energy exploitation including incentives and regulations.

The Work Plan of Annex I started in 2002. It was designed for a period of five years.

The Instituto Nacional de Engenharia e Tecnologia Industrial (INETI) is designated as the Operating Agent for this Annex acting through ADENE (Portuguese Energy Agency).

Annex II: Development of Recommended Practices for Testing and Evaluating OES

The objective of Task II set on 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 Work Plan of Annex II was initially designed for two years and was prolonged to three years in the 5th ExCo meeting.

The Danish Energy Authority, Ministry of Economic and Business Affairs of Denmark is designated as Operating Agent acting through RAMBOLL.

		TASKS	CN	DK	EC	IR	JAP	PT	UK
			CONTRACTING PARTIES						
Operating Agent: INETI acting through ADENE (Agência para a Energia)									
ANNEX I	**I**	Review, Exchange and Dissemination of Information on OES	X	X	X	X		X	X
	I.1	Collation, review and publication of information on ocean waves and marine currents energy systems							
	I.2	Exchange of information on OES							
	I.3	Analysis and dissemination of information on OES							
	I.4	Website creation and maintenance							
Operating Agent: Danish Energy Authority (Energistyrelsen) acting through RAMBOLL									
ANNEX II	**II**	Development of Recommended Practices for Testing and Evaluating OES	X	X	X	X	X	X	X
	II.1	Testing facilities and test sites							
	II.2	Testing procedures							
	II.3	Presentation of results							

Table 2 | Participation in OES Tasks (Status: end 2003)

The involvement of the Participants in the two current Annexes during 2003 is shown in Table 2. The Tasks leadership is the responsibility of the respective Operating Agent.

Efforts to expand the activities in the Agreement have continued during 2003. The Executive Committee has been considering additional Annexes.

2 THE EXECUTIVE COMMITTEE

2.1 Meetings

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 determine other specific activities and to approve the budget to administer the Agreement.

A secretariat assists the ExCo in planning meetings, assisting the members, providing information to the IEA Secretariat, disseminating information and preparing the annual reports. The ExCo secretariat is based in Lisbon, and is run by Dr. Ana Brito Melo.

Dr. Teresa Pontes from Portugal continued to be the chair of this ExCo during 2003 and was reelected at the 5th Executive Committee to continue in 2004. Mrs. Katrina Polaski, the Irish Member was elected to serve as Vice-Chair in 2004.

The contact details for the ExCo members can be found in Appendix 1.
The following ExCo meetings were held during the year 2003:

> 4th ExCo meeting in Paris, France on March 4th.

> 5th ExCo meeting in Cork, Ireland on October 23th-24th.

4th ExCo meeting
The 4th ExCo meeting was held jointly with the events occurring at the IEA offices in Paris on 3th-4th March: the IEA Renewable Energy Working Party (REWP) Seminar "R&D Priorities to

Create a Hydrogen Infrastructure", and the REWP 43 Meeting.
All Member Countries were presented in this meeting. The ExCo welcomed Canada and the European Commission which had recently formally joined the Agreement. The number of participants was 12, 8 Members and 4 Observers (1 from Australia, 1 from the UK and 2 from USA).

During this meeting the following main issues were discussed and decisions were taken:

> **Newsletter** - The first issue of the IEA-OES Newsletter was approved.
> **Website** - New plans for the development of the IEA-OES Website were presented, namely the intention of creating a "Members Area", accessible through an individual password to be used as a tool for dissemination of documents among the Members.
> **Relevant events** - The ExCo discussed its participation in the IEA Technology Collaboration Fair to take place during the IEA Ministerial meeting on 28th-29th April, as a means to call the attention of these very high level visitors to the need of research and the work already carried out within the IEA-OES. The Members were also encouraged to submit papers regarding the activities of the Implementing Agreement in appropriate conferences such as the Fifth European Wave Energy Conference to be held at University College Cork, Ireland, in September2003.
> **IEA-OES Publications** - The Publication of Annex I report "Status and Research Priorities for Ocean Energy technology" and Annex II report "Development of Recommended Practices for Testing and Evaluating Ocean Energy Systems" was approved.
> **Sponsors** - Sponsorship as means for participation in the Agreement of companies from countries whose governments would not be interested to become Contracting Parties was discussed. No decision on the conditions to sponsorship was decided.
> **Annex II** - The Operating Agent proposed the extension for one year (from two to three years) which was approved. Further, the possibility of the work programme to proceed with the collaboration of working groups was accepted.

Figure 1 | 4th ExCo meeting participants

From left to right:

In front: Katrina Polaski (Ireland ExCo member)
Yasushi Tsuritani (Japan ExCo member)
Ana Brito Melo (Portugal ExCo secretary)
Teresa Pontes (Portugal ExCo member, chair)
Gouri Bhuyan (Canada ExCo member)

Behind: Kim Nielsen (Denmark ExCo member)
Alla Weistein (Ireland ExCo observer)
David Bramble (UK ExCo member)
Jan Bunger (Denmark ExCo alternate)
Philippe Schild (UE ExCo observer)
Cynthia Rudge (Australia ExCo observer)
John Spurgeon (UK ExCo observer)

Figure 2 | 5th ExCo meeting participants

From left to right:

In front: Gouri Bhuyan (Canada member)
Katrina Polaski (Ireland member)
Teresa Pontes (Portugal member, chair)
Philippe Schild (UE ExCo)
Robert Tresher (USA observer)

Behind: Tsuyoshi Miyazaki (Japan member)
Yasushi Tsuritani (Japan member)
Yasuyuki Ikegami (Japan member)
Peter Goldman (USA observer)
Ana Brito Melo (Portugal secretary)
Kim Nielsen (Denmark alternate)
Alla Weistein (USA observer)
John Overton (UK member)
Hiroyuki Osawa (Japan member)

> New Annexes - The opportunity and interest of two new Annexes: Annex III - Market Facilitation for Ocean Energy Systems and Annex IV - Data Base Resource were approved.

5th ExCo meeting

The 5th ExCo meeting was held in Cork, Ireland, prior to the 5th European Wave Energy Conference, a relevant event in the field of Wave Energy Utilisation. Fifteen Members and Observers participated in the ExCo meeting: 8 Members and 7 Observers: 4 from USA (1 representing the State of Hawaii), 2 from Japan and 1 from Italy.

During this meeting the following changes on ExCo members were proposed and approved:

> Change of ExCo members - Mr John Overton (from DTI) replaced Mr David Bramble (from DTI) as ExCo Member for United Kingdom. Dr. Tony Lewis (from Hydraulics and Maritime Research Centre University College Cork) replaced Mr. Godfrey Bevan (from Sustainable Energy Ireland) as Alternate Member from Ireland.

> Change of Contracting Party - The Japanese Member announced the intention of JAMSTEC to withdraw as Contracting Party to this Implementing Agreement due to the fact that the R&D work on wave energy had stopped at JAMSTEC with the finalisation of the Mighty Whale project. However, Japan announced the intention of the Institute of Ocean Energy (IOES), Saga University to replace JAMSTEC as Contracting Party to this IA. This change was approved.

The ExCo discussed the **"IEA Framework for International Energy Technology Co-operation"** approved by the IEA Governing Board in April 2003, which replaces the former Guiding Principles (see above). To follow this Framework the IEA Secretariat recommended a set of provisions to be amended in the IEA-OES Guiding Principles .These were analised by the ExCo it being decided to circulate a summary document among the Members with the proposed modifications, to be discussed in the first 2004 ExCo meeting.

Further, the ExCo took the following main initiatives:

> **National Activities** - To produce a country review questionnaire to collect information on national activities of Member Countries.

> **R&D Long term** - In order to summarise the needs for long-term R&D an ExCo subgroup was set up. This work is to be made based on the Annex I Report "Status and Research and Development Priorities. Wave and Marine Current Energy Status" produced by DTI under the Annex I. The Danish Member Kim Nielsen and the EC Member Philippe Schild volunteered to produce this summary.

> **Expert meeting under Annex II** - It was decided to organise an expert meeting to establish the baseline to proceed with the work under the Annex II, presented in the report "Development of recommended practices for testing and evaluating ocean energy systems" published by the IEA-OES in April 2003. It was suggested that this expert meeting should be held on the occasion of the kick-off meeting of the new EC contract "Coordination Action on Ocean Energy". Kim Nielsen and Philippe Schild volunteered to organise this meeting.

> **New Annexes** - A revised proposal for Annex III –"Market Facilitation for Ocean energy Systems" presented by the Irish Member Katrina Polaski was discussed and approved. The collection of information on national activities to be obtained under the scope of Subtask I – "Country Review of Market Dynamics for Ocean Waves and Marine Currents Energy Systems" is a first contribution for the activities on market issues. A summarised draft proposal for Annex IV – "Resource, Infrastructure and Environmental Assessment" was presented by the Portuguese Member Teresa Pontes. It was agreed to be appropriate to consider setting a new Annex on this topic. A complete draft should be presented later.

2.2 New Participants

The European Commission and **Canada** signed this Implementing Agreement in early 2003. Interest from potential Member Countries continued to be strong along this year. An Observer from **Italy** participated in the 5th ExCO meeting and the Chairman of the European Seminar "Offshore Wind Energy in Mediterranean and other European Seas" invited and the IEA-OES ExCo Chair to present the IEA-OES at this event that was held in Naples in April 2003.

Observers from **USA** actively participated in the 4th and 5th ExCo meetings. These Observers include a developer of a wave energy device, the US Alternate Delegate to the IEA Renewable Energy Working Party (who is with the DoE) and a Representative of the State of Hawaii (Assistant Minority Floor Leader of the House of Representatives) who expressed the strong will of the House of Representatives for the development of wave power as a renewable energy resource for this State. She showed intention in participating in further meetings.

Researchers from **Norway** also expressed the interest of their country to join the Agreement. Contacts have been sustained with **Australia**, **New Zeeland** and **Mexico**.

2.3 New Initiatives

Although ocean energy technologies are still in a pre-commercial stage, it had been decided to start preparing a new Annex "Market Facilitation for Ocean Energy Systems" as a means to support and speed up the commercial uptake of these technologies. The draft work programme concentrates on the analysis of the technical, market and policy barriers to the commercialisation and broad uptake of ocean energy systems and on recommending strategies to overcome these barriers.

The Subtask I "Country Review of Market Dynamics for Ocean Waves and Marine Currents Energy Systems" can be considered as a preparation measure for this new Annex. For this purpose a questionnaire was prepared requesting information on governmental, commercial and utility activities on ocean energy systems. It includes the following topics :

> Description of policy initiatives and programmes that support ocean energy systems, and those initiatives and programmes that support other renewable energy systems but do not specifically include ocean energy systems.

> List of entities conducting research on ocean energy systems and the with a description of their activities.

> List of companies created to develop and commercialise ocean energy systems, including the type of technology and its potential for market adoption, company profile, business development plan and sources of corporate funding and project funding for the projects under development.

> List of companies and agencies capable of providing products and services that will enable or are compatible with the development and utilisation of commercially deployed ocean energy systems, including the identification of the services and products available.

> General market potential for ocean energy systems based on a standardized methodology, to be developed using publicly available ocean energy resource data for each general ocean energy system – wave (shoreline and offshore); marine currents; tidal and ocean thermal.

The structure of the questionnaire is presented on the right:

FORM A - NATIONAL PROGRAMNMES

> Organisations supporting ocean energy
> National Policy for Renewables
> National Policy for Ocean Energy
> Targets for renewable energy
> Targets for ocean energy
> Specific programmes in place to deliver ocean energy targets
> Programmes that support other RE technologies but are not available to ocean energy

FORM B - ESTIMATED RESOURCE AND TECHNICAL, PRACTICAL AND ECONOMIC BARRIERS TO OCEAN ENERGY SYSTEMS IMPLEMENTATION

> Estimated resource on Ocean Wave Shoreline, Ocean Wave Offshore, Marine Currents, Tidal and OTEC
> Technical, practical and economic constraints considered in the above resource estimations
> Technical, practical and economic barriers NOT considered in the above resource estimations

FORM C - ORGANISATIONS RESEARCHING OCEAN ENERGY SYSTEMS

> Organisation researching Ocean energy Systems
> Outline of activity focus
> Prior experience with ocean energy research (significant projects only)
> Fundamental and Applied Research
> Testing facilities existing for ocean energy research
> Pilot plants/Prototypes
> Promotion of ocean energy
> Number of staff engaged
> Primary sources of funding

FORM D - COMPANIES FORMED TO COMMERCIALISE OCEAN ENERGY SYSTEMS

> Companies formed to commercialise Ocean Energy Systems
> Identification of the device
> Status of device development
> Potential market
> Business development plans
> Source of corporate funding
> Source of project funding

FORM E - COMPANIES AND STATE AGENCIES CAPABLE OF PROVIDING SERVICES OR PRODUCTS THAT ENABLE OCEAN ENERGY EXPLOITATION AND DEVICE DEVELOPMENT

> Companies and state agencies capable of providing services or products
> Current links with ocean energy research institutes or commercial entities

2.4 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. 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, the production of IEA-OES publications including the Newsletter, Annual Report and other material for dissemination of the general activities.

Total funds received in 2003 amount to 42000 Euros with annual contribution of 7000 Euros by each of six members (Denmark, Portugal, UK, Japan, Ireland and the European Commission).

Participation in relevant Conferences and Seminars 3.1

OWEMES 2003
Offshore Wind Energy in Mediterranean and other European Seas - Resources, Technology and Applications
April 10th – 12th, 2003
Naples, Italy
The aim of this European seminar was to make a specific and up-to-date review of ongoing activities and programmes in order to exchange information and promote co-operation among European, Mediterranean and other countries world-wide in the promising field of wind and other marine energy applications.
The Chair was invited to and made the presentation "IEA Implementing Agreement on Ocean Energy Systems".

Energy Technology Fair - IEA Ministerial Meeting
April 28th - 29th, 2003
Paris, France
The International Energy Agency welcomed the Energy Ministers of IEA Member Countries for their biennial meeting in Paris and organized at the same period of time the Energy Technology Fair. This was an opportunity to exhibit the starting work of the Implementing Agreements to the Energy Ministers and other high level politicians. Highlights of the achievements of the IEA Energy Technology Collaboration Programme, including Implementing Agreements and Working Parties as well as some National Programmes on technology development were presented.

Figure 3 | Participation of the IEA-OES at the Energy Technology Fair

The Implementing Agreement on Ocean Energy Systems participated, presenting its 2002 Annual Report, the first issue of the IEA-OES Newsletter and an illustrative poster that is available at the IEA-OES webpage.

SUSTAIN 2003

May 13th – 15th, 2003

Amsterdam, The Netherlands

The fourth edition of the international trade World Sustainable Energy Exhibition focused on the production and application of sustainable energy. The conference dealt with strategic and commercial aspects and case studies in the area of sustainable energy generation, applications and CO2 emission reduction in the different industries.

The Chair was invited and presented a state of the art on ocean energy technologies, with special focus on wave and marine currents. The presentation "Utilisation of technologies for enhanced sustainable energy production from the ocean" was included in the session "State of the Art Technologies I - Cases in Biomass & Wave Energy".

OMAE 2003

June 8th -13th, 2003

Cancun, Mexico

In the 22nd International Conference on Offshore Mechanics and Arctic Engineering the Chair made an oral presentation of the activities of the IEA-OES.

Fifth European Wave Energy Conference 2003

September 17th – 20th, 2003

Cork, Ireland

The Fifth European Wave Energy Conference was the latest in a (generally biannual) series started in 1993 focusing Wave and Marine Currents Energy developments. The programme offered a range of topics in all aspects of Ocean Energy Research and Development:

> Public Policy & International Cooperation
> Specific Device Modelling
> Full Scale Devices
> Pneumatic Device Modelling
> Tidal Energy
> Full Scale Component Trials
> Power Take-off Systems
> Hydrodynamics and Device Modelling
> New Concepts and Testing Methods
> Wave Energy Resource/Environmental Issues

This conference has become an international forum where those active in the field present their work and results, it being a relevant event to all involved in ocean energy development. The number of participants was about 170 from 20 countries, including researchers, device developers, system manufacturers, utilities, government agencies officials and companies. In the European Wave Energy Conferences the number of participants from companies has been increasing it being about 50% in this last one. The Chair presented a paper entitled "International Energy Agency – Cooperative R&D on Ocean Energy" by M. T. Pontes and A. Brito-Melo which provides an overview of the activities carried out under the Agreement.

Other related events

PNWER - Pacific NorthWest Economic Region Summit
July 13th - 17th, 2003, Calgary, Alberta, Canada

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Figure 4 | Issue 1 _ February 2003

Figure 5 | Issue 2 _ September 2003

PNWER holds at least one meeting every year where all the working groups, councils, and committees meet to discuss current issues of regional concern and develop action plans related to these concerns. Throughout the year, other smaller meetings may occur, such as individual working group meetings, special committee meetings, or a meeting of the PNWER Executive Committee. The Canadian Member of the IEA-OES presented in this Summit an overview on ocean energy technologies and a brief introduction to this Implementing Agreement activities.

Renewables 2003

December 1st – 2nd, 2003, Calgary, Alberta, Canada

The theme of this National Summit was "Commercializing Renewable Power Projects - Building Reliable Energy Portfolios", in which the Canadian Member of this Agreement has also presented an overview on ocean energy technologies and a brief introduction to the Implementing Agreement activities.

3.2 Promotion and Communication

Newsletter

The bi-annual Newsletter of the IEA Ocean Energy containing information targeted at audiences who are unfamiliar with this issue has been widely distributed both within the Member Countries and at major conferences and seminars. It is available at the IEA-OES website.

The Newsletter is a collaborative publication of the Member Countries who provide contributions on reference, ongoing and planned activities and programmes. The last page of the Newsletter is dedicated to information on the IEA-OES activities, relevant events and includes the Members contacts.

To the first issue Canada contributed with a summary of the Vancouver Island Wave Demonstration Projects, the Danish Member suggested to contact developer of the wave energy converter Wave Dragon who provided an article on recent developments of this device and the Japanese Member provided a description of the "Mighty Whale" R&D project. This is an offshore device whose development and testing was completed in 2002 (Fig. 6).

To the second issue, the Irish Member provided an article on the recent development of the McCabe Wave Pump that is a wave energy device specifically designed for desalinization (Fig. 7). Portugal has contributed with a presentation of the wave power plant on the island of Pico, Azores and the UK suggested to contact the developer of the "Seaflow" (an offshore tidal current turbine) who provided a short report on this project (Fig. 8).

Website

As decided in the 4th ExCo meeting, during 2003 the website (www.iea.oceans.org) was upgraded the main new feature being the Members Area designed to be used for Executive Committee documents.

This new feature is accessible through an individual password. It is a tool for dissemination of documents among the Members namely to enable consulting agendas, minutes and other internal documents.

Reports and publications

The following IEA-OES reports were published in 2003:

WAVE AND MARINE CURRENT ENERGY - STATUS AND RESEARCH AND DEVELOPMENT PRIORITIES | 2003

The aim of this report is to guide the establishment of new R&D activities within this Agreement, being also useful for setting up national and international R&D programmes.

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Figure 6 | Mighty Whale (courtesy of JAMSTEC)

Figure 7 | The McCabe Wave Pump (Hydam Technology Ltd.)

Figure 8 | Seaflow project (courtesy of Marine Current Turbines Ltd)

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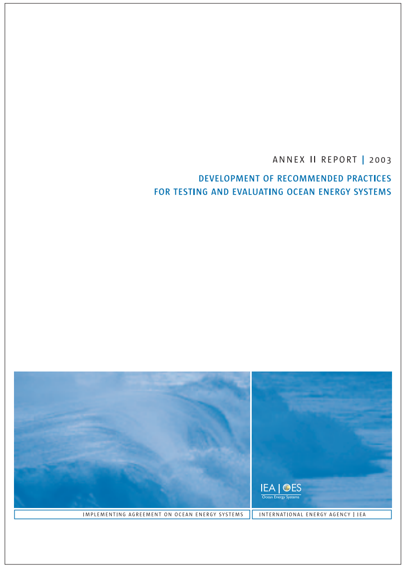

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Figure 9 | Annex I Report

Figure 10 | Annex II Report

It was developed within the scope of the Annex I of the IEA-OES and was prepared under contract by AEA Technology, Future Energy Solutions as part of New and Renewable Energy Programme of the United Kingdom Department of Trade and Industry.

It 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 presents Ocean Energy System R&D priorities with special focus on generic research.

DEVELOPMENT OF RECOMMENDED PRACTICES FOR TESTING AND EVALUATING OCEAN ENERGY SYSTEMS | 2003

This report was developed within in the scope of the Annex II of the IEA-OES and prepared by the Operating Agent of this Annex. The publication was funded by the IEA-OES common fund.

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, it provides guidelines for standards for testing, preliminary costs assessment and presentation of results. The guidelines have been prepared based on principles developed as part of the Danish Wave Energy Program 1997 – 2001.

These reports as well as the Annual Reports are available either from the IEA-OES website (www.iea-oceans.org) or from the Executive Secretary (iea.oes@ineti.pt).

Dissemination of publications by the IEA-OES is also made through The IEA OPEN Energy Technology Bulletin.

In the year 2003 the ExCo decided to start including in its Annual Report a section on National Activities, describing the ocean energy activities in the Member Countries, national policies, research, demonstration and (pre)-commercial activities.

All Member Countries provided their contribution except Japan whose activity on the technologies presently covered by the IEA-OES (the Mighty Whale project) had been completed in 2002. (As mentioned above, Saga University who develops activity on OTEC will become the new Japanese Contracting Party.)

4.1 National Policy

Canada

Renewables

Policy is focused in assisting emerging renewable energy sources to become full-fledged competitors in the marketplace. Main policy drivers are:

- Environmental - climate change, sustainable development, clean air
- Economic/Energy - innovation (technology development, manufacturing and export opportunities) and ensuring long term energy security

No national target for renewable energy exists in Canada. Some provinces are considering the establishment of Renewable Portfolio Standards.

Ocean Energy

No specific national policy exists for ocean energy. However, there has been growing interest to exploit the potential wave and tidal current resources in British Columbia. Encouraged by

COUNTRY	ORGANISATION	WEBPAGE
CANADA	BRITISH COLUMBIA MINISTRY OF ENERGY AND MINES	WWW.GOV.BC.CA/EM
	BRITISH COLUMBIA HYDRO	WWW.BCHYDRO.COM
	NOVA SCOTIA POWER CORP. (ANNAPOLIS TIDAL GENERATING STATION)	WWW.NSPOWER.CA
	POWERTECH LABS INC.	WWW.POWERTECHLABS.COM
DENMARK	DANISH ENERGY AUTHORITY THROUGH THE NATIONAL DANISH ENERGY RESEARCH PROGRAMME (APPLIED R&D)	WWW.ENS.DK
	ELECTRICITY TRANSMISSION SYSTEM OPERATOR - ELTRA (VESTERN PART OF DENMARK)	WWW.ELTRA.DK
	ELECTRICITY TRANSMISSION SYSTEM OPERATOR - ELKRAFT SYSTEM (EAST) THROUGH THE CLEANER ELECTRICITY PRODUCTION R&D PROGRAMME (PSO – PUBLIC SERVICE OBLIGATION PROGRAMME)	WWW.ELKRAFT-SYSTEM.DK
IRELAND	SUSTAINABLE ENERGY IRELAND	WWW.SEI.IE
	THE MARINE INSTITUTE	WWW.MARINE.IE
	ENTERPRISE IRELAND	WWW.ENTERPRISE-IRELAND.COM
PORTUGAL	MINISTRY OF ECONOMY	WWW.PRIME.MIN-ECONOMIA.PT
	PORTUGUESE FOUNDATION FOR SCIENCE AND TECHNOLOGY	WWW.FCT.MCES.PT
		WWW.ADI.PT
UNITED KINGDOM	DEPARTMENT OF TRADE AND INDUSTRY	WWW.DTI.GOV.UK
	ENGINEERING AND PHYSICAL SCIENCES RESEARCH COUNCIL	WWW.EPSRC.AC.UK
	THE CARBON TRUST	WWW.THECARBONTRUST.CO.UK

Table 3 | Organisations supporting Ocean Energy

the rising electricity demand for Vancouver Island and as part of the initiatives on green energy technologies, BC Hydro examined the feasibility of exploiting wave and tidal current energy in the province and developed relevant resource maps. In 2002, BC Hydro signed memorandum of understanding (MOU) with Energetech Australia and Ocean Power Delivery of UK to build two wave demonstration plants in Vancouver Islands. Though these MOUs were cancelled in 2003 because of the implementation of a new provincial energy policy restricting BC Hydro's direct involvement in new energy generation, efforts by private companies to enable development of ocean energy in BC are continuing. Presently there are five different companies who are in the process of developing wave & tidal current technology and/or project in the province.

Specific programmes in place to deliver ocean energy targets:

There is no specific program 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).

Programmes that support other RE technologies but are not available to ocean energy:
Examples of such programs are:

> Wind Power Production Incentive (WPPI): Established in 2002, this initiative will provide financial support for the installation of 1,000 megawatts of new capacity over five years. (http://www.canren.gc.ca/programs/index.asp?CaId=107&PgId=622).
> Renewable Energy Deployment Initiative (REDI): The purpose of this program is to stimulate the market demand for commercially reliable, cost-effective renewable energy systems for space and water heating and cooling (http://www2.nrcan.gc.ca/es/erb/erb/english/View.asp?x=455).

Denmark

Renewables

From the National Danish point of view renewables can play an important role to secure a cost effective energy supply in the medium and long term, to improve both economic growth and the environment - not least through renewables contribution to fulfill Denmark's international CO_2 emission reduction commitments. The policy for implementing renewables in Denmark is that the further expansion of the use of renewables shall be facilitated within the common EU-framework – that is the EU Quota Directive for CO_2 emissions and the Renewable Energy Directive inter alia. Renewables shall be integrated in the liberalised electricity market through market instruments. The former special economic support schemes for renewables are to a higher degree being converted into market based framework conditions. The policy includes the use of public support programmes for pre-commercial research and development within new energy technologies. By law, the electricity production from the first plants of a new energy technology may receive a fixed (not market based) price when sold to the grid.

There is one official target for 2003 – 20 % of the electricity consumption in Denmark shall be delivered from renewables. The target will be more than fulfilled – the actual prognosis is up to 25 %. Onwards the market – under the appropriate framework conditions – will decide the actual amount of electricity based on renewables in the overall Danish mix of electricity origin.

Ocean Energy

There is no dedicated policy for ocean energy and no specific target. It is supported under the common framework for supporting new energy technologies.

Specific programmes in place to deliver ocean energy targets:
There is no specific ocean energy programmes.

Programmes that support other RE technologies but are not available to ocean energy:
None. All programmes may support qualified ocean energy projects.

Ireland

Renewables

The Green Paper on Sustainable Energy set policy for Ireland on renewable energy. The key policy elements include a target to increase the capacity of renewable energy by 500 MW installed from existing capacity in 2000 by the year 2005. No specification of technologies to be used was identified. The target was to be met by annual rounds of the competitive tender programme "the Alternative Energy Requirement" and by renewables selling directly to energy customers. The market for energy in Ireland is opening progressively through this time period with full opening expected by end 2005. Renewable energy generated electricity was given access to the entire market in 2000, thus can access customers that otherwise would only have access to buy electricity from the incumbent monopolist. Two round of AER have been launched since the document release. Bidders representing a total of 578 MW of capacity were offered power purchase agreements with the incumbent monopolist under the programme. Ocean energy was not included in either of the AER calls for tender.

The key target in place is the Green Paper target to increase the capacity of renewable energy by 500 MW installed from existing capacity in 2000 by the year 2005. This target has also been converted to a carbon abatement from renewable energy target in the National Climate Change Strategy. Finally, the EU directive on the promotion of renewable energy in the internal electricity market gave an indicative target for Ireland to have 13.2% of energy consumption come from renewable energy sourced electricity by the year 2010.

Ocean Energy

There currently is no specific national policy for ocean energy in Ireland. A consultation document was launched in 2002 on options for the development of ocean energy in Ireland. The consultation process, while not resulting in a government commitment to an ocean energy policy, did result in the informal organisation of a cooperative approach to research in to an appropriate policy approach amongst the energy agency in Ireland and the agency responsible for marine activities.

No targets exist for Ocean Energy and no Specific programmes in place to deliver ocean energy targets.

Specific programmes in place to deliver ocean energy targets:

No specific targets for ocean energy exist.

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

The Alternative Energy Requirement competitive tender programme has been used most recently to support wind energy onshore and offshore, biomass landfill gas, biomass CHP, biomass anaerobic digestion, and small scale hydro. Calls for tenders under the programme designate a specific amount of capacity from specific technologies for which tenders are being sought. The tenders received are ranked according to bid price in each technology and contracts are offered to the projects with the lowest bid prices up to the amount of capacity designated in the call. Ocean energy was included in a previous AER round, however the winning bidder did not build and surrendered the contract. It is likely that should further rounds of the Alternative Energy Requirement programme be launched that ocean energy would be included in future rounds.

Portugal

Renewables

The Portuguese Energy Policy pursues a set of objectives that includes, among others:

> the reduction of energy dependence and the development of endogenous energy resources;

> the reduction of the environmental effects of the production and use of energy.

The national policy measures assigned priority to create favourable conditions for renewable energy sources and to encourage private investment, through project support programmes. The legal basis for supporting the implementation of RE production was introduced in 1989 establishing regulatory rules for independent electricity production. Since 1995 the Portuguese electricity market is liberalised. The present remuneration scheme was introduced in 1999, which takes into account the environmental benefits of RE electricity and introduces more transparent procedures regarding the permission process and the interconnection points for RE power plants. Finally in 2001, the existing legal diploma was revised, updating and further differentiating the tariff rates by technology and operating regime.

The Portuguese strategy for the promotion of renewables is formulated in the E4 Programme (Energy Efficiency and Endogenous Energies) launched in October 2001 by the Ministry of Economy. One main line of action is focused on RES: promoting the use of endogenous energy sources by establishing a highly dynamic compromise between technical and economic feasibility and environmental constrains. With the E4 Programme and subsequent legislation, the Portuguese Government set up a number of measures for the country to produce in 2010 39% of power generation from renewable sources that had been agreed within the European Directive for Electrical Energy.

The main instruments to promote renewable energy in Portugal are:

> National investment subsidies (including tax incentives)
> The legal framework for feed-in tariffs for the production of electricity from RES.

A relative new programme was launched by the Ministry of Economy comprising a complete set of funding incentives to the promotion of renewable energy, the Operational Program for Economic Activities – POE (Programa Operacional da Economia) - under the third Community Support Framework (QCA III). This programme was re-formulated to the actual incentive scheme PRIME (Programa de Incentivos à Modernização da Economia), for the period 2000-2006.

Ocean Energy

A published law in 2001 established differentiated payments based on the type of technology and an operating regime for electricity production from renewable sources which now defines and positions wave energy among other renewables. As a result a feed-in tariff in the range of 0.22-0.25 Euro can typically be achieved by wave power plants.
A recently published Resolution of the Council of Ministers indicates a 50 MW target of installed wave power by 2010.

Specific programmes in place to deliver ocean energy targets:

Portugal does not have specific programmes for ocean energy. The available programmes are generic for RE technologies.

Within the PRIME programme (Programa de Incentivos à Modernização da Economia) launched by the Ministry of Economy for 2000-2006, there exists measures that can be used to support R&D on ocean energy. R&D projects are also funded by the Portuguese Foundation for Science and Technology under the Programme POCTI - Operational Programme for Science, Technology and Innovation, co-financed by Community funds, under the programme QCAIII.

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

It is currently available a measure established in order to enforce the integration of 'mature' RE in the national electricity system which is presently limited to wind energy, geothermal, biomass, solar and mini-hydro power.

United Kingdom

Renewables

The UK's Energy White Paper (published in February 2003) "Our energy future – creating a low carbon economy" recognized that the energy sector requires very long-term investment and looked ahead to 2050 to set the overall context of energy policy. The paper set out the challenges the UK faces on the environment, the decline of indigenous energy supplies, the need to update the energy infrastructure, and the policies required to pursue these challenges over next twenty years and beyond. It set four goals for the UK's energy policy:

> To put the UK on the path to cut carbon dioxide emissions 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 Government has set itself a target of securing 10% of electricity from eligible, renewable sources by 2010, and 15% eligible, renewable sources by 2015. There are four elements to the new strategy in support of renewable energy.

- The Renewables Obligations
- Climate Change Levy Exemption
- Capital Grants and Planting Grants for Energy Crops
- Research and Development Programme.

The Renewable Obligation and the Research and Development Programme are particularly relevant to Ocean Energy Systems.
The Renewables Obligation requires electricity suppliers to source a specific proportion of their electricity from renewables. This proportion rises each year starting with 3% in 2002/3 and reaching 10.4% in 2010/11. This will shortly be increased to 15% in 2015. Proof of meeting the requirement is by presenting certificates for each unit of renewable electricity. This has led to the development of a market in "Renewables Obligation Certificates", or ROCs, from which renewable generators can derive income.

The UK has a renewable energy R&D programme that spends approximately 15M GBP annually on a wide range of projects on most RE technologies.

The Energy White Paper stated the UK's aspiration for renewables to meet 20% of its electricity needs by 2020. The UK has set a legal target for the electricity supply industry to generate 10 per cent of its electricity from renewable sources by 2010, recently increased to 15% in 2015, to move towards this aspiration. The UK is currently in the process of developing a set of regional renewable energy strategies that will involve setting targets at a regional level.

Ocean Energy

The UK has a relatively large R&D programme in wave and tidal energy, with several large projects currently being funded. These include the Seaflow project, the Stingray and the Pelamis, as well as several others. Apart from the capital grants programme – for offshore wind and biomass - the UK's support mechanisms for renewable energy do not differentiate between technologies. If ocean energy approaches commercial reality then it is possible that capital grants similar to those for offshore wind could be considered. The UK has committed in excess of £15 million since 1998 to the development of wave and tidal stream energy devices.

The UK has targets for renewable energy as a whole, but currently does not break these down to the level of specific technologies.

Specific programmes in place to deliver ocean energy targets:

The UK does not have specific targets for ocean energy, but does have a number of relatively large R&D projects underway (see section on "National Policy", above). In addition the Government has recently undertaken a Renewables Innovation Review, covering all renewable energy technologies. One aspect of the Review has been looking at how the future framework set by Government can best support wave and tidal technologies through their various stages of development.

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

The capital grants schemes are currently only available to offshore wind, biomass burning, energy crops and photovoltaics. However, if ocean energy technologies approach commercial reality then it is possible that the scheme may be extended to include it.

Overview of Research Activities 4.2

Aalborg University, Denmark

The activity in ocean energy at Aalborg University is focused on model testing of scale models of wave energy converters and field testing in sheltered open sea. Prior experience with ocean energy research was devoted to the following projects:

> Wave Dragon 1:4.5 (EU-proj: ENK5-CT-2002-00603)
> Low-Pressure Turbine and Control Equipment for Wave Energy Converters (EU-proj: JOR3-CT98-7027)
> Commercial model testing of approx. 20 different wave energy devices.
> State-of-the-art report about wave energy for Statkraft.

Fundamental and Applied Research has concerned wave analysis, wave forces on maritime structures and overtopping of maritime structures. The following testing facilities exist for ocean energy research: a Wave Basin (8.5 meter x 15.5 meter) for short crested waves, a Wave Basin (18 meter x 14 meter) for short crested waves and 3 Wave Flumes.

Hydraulics and Maritime Research Centre of the University College Cork, Ireland

The Hydraulics and Maritime Research Centre (HMRC) of the University College Cork (UCC) is principally a dedicated research facility that also offers a teaching and education function, established in UCC in 1979. It houses the only facilities for wave simulation in Ireland. The major facility is the Ocean Wave Basin, which is 20m long and 18m wide and 1m deep with 40 independent wave-generating paddles. Other tanks include two wave flumes and a shallow coastal basin which are all computer controlled.

The staff at the Centre has wide experience mainly in experimental tank testing of wave energy

COUNTRY	ORGANISATION	WEBPAGE
DENMARK	AALBORG UNIVERSITY	WWW.CIVIL.AUC.DK
IRELAND	HYDRAULICS AND MARITIME RESEARCH CENTRE OF THE UNIVERSITY COLLEGE CORK	WWW.UCC.IE/RESEARCH/HMRC/
	QUEENS UNIVERSITY OF BELFAST	WWW.QUB.AC.UK
PORTUGAL	IST - INSTITUTO SUPERIOR TÉCNICO, TECHNICAL UNIVERSITY OF LISBON	WWW.IST.UTL.PT
	INETI – INSTITUTO NACIONAL DE ENGENHARIA E TECNOLOGIA INDUSTRIAL	WWW.INETI.PT
	WEC – WAVE ENERGY CENTRE	WWW.WAVE-ENERGY-CENTRE.ORG
UNITED KINGDOM	THE ROBERT GORDON UNIVERSITY	WWW.RGU.AC.UK
	LANCASTER UNIVERSITY	WWW.ENGINEERING.LANCS.AC.UK
	EDINBURGH UNIVERSITY	WWW.MECH.ED.AC.UK/RESEARCH/WAVEPOWER/

Table 4 | Organisations with research on Ocean Energy

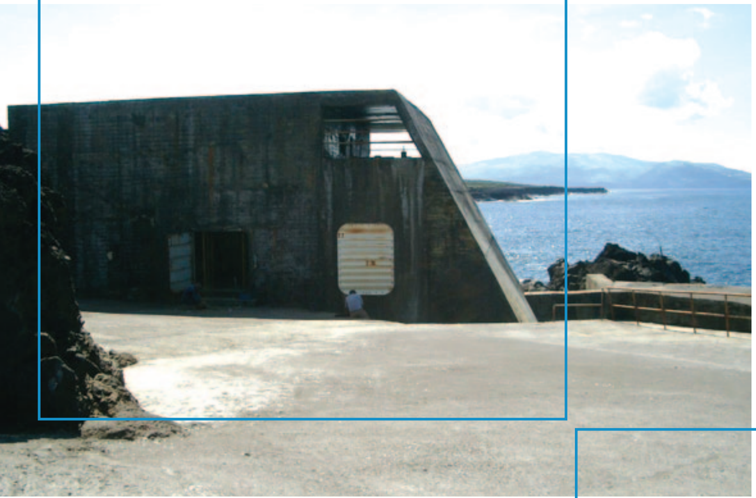

Figure 11 | European Pico Power Plant, Azores, Portugal

devices, coastal and offshore structures. The HMRC have been involved in the physical tank testing of several wave energy systems, namely the A.W.S. Device, WavePlane, I.P.S. Buoy, Wave Dragon, Azores O.W.C., McCabe Wave Pump, Backward Bent Duct Buoy, SPERBOY, Rock OWC, SEKE Device, WaveBOB. HMRC collaborates closely with the Department of Applied Mathematics of UCC, who has extensive experience in mathematical modelling of wave-energy related tasks.

Queens University of Belfast, Ireland

The wave power team at Queen's was formed in 1976. The team has been engaged with all aspects of wave energy conversion and has co-ordinated the research, design, construction and operation of two shoreline wave power plant commissioned in 1989 and 2000 respectively. The team was awarded the Royal Society ESSO Energy prize in 1994 in recognition of the merit of their pioneering work on the first plant, a 75kW unit located on the Isle of Islay off the West coast of Scotland, UK.

The latter plant, known as LIMPET is owned by an SME, Wavegen, but QUB have access to the plant and are contracted to acquire data and monitor its performance. The team has the largest data base in the world acquired from working wave power plant between 1989 and 1996 (1st Plant) and since 2000 (LIMPET plant).

IST - Instituto Superior Técnico, Portugal

Research on wave energy started in Portugal in 1978 at IST. The oscillating water column (OWC) was chosen for most of the R&D work, but in 1997 collaboration started with the AWS B.V. to develop the AWS device. At the Mechanical Engineering Department, the studies were devoted to the hydrodynamics of the wave energy absorption (theoretical and experimental), development of mechanical equipment for wave energy converters (especially air turbines of Wells type), control strategies, including phase control and conceptual design of wave energy devices.

IST was responsible for, and co-ordinated, the basic studies, design and construction of a wave energy pilot plant (400 kW) at the island of Pico, Azores, which started commissioning tests in October 2001. The IST team has had a substantial experience in co-ordinating and participating in EU projects. Within the scope of one of these projects, IST was involved in the conceptual design and numerical hydrodynamic modelling of LIMPET OWC plant in Islay.

INETI – Instituto Nacional de Engenharia e Tecnologia Industrial, Portugal

Research on wave energy has been carried out at INETI since 1983 and its activities were initially focused on resource assessment. Further activities involve modelling (theoretical, numerical and tank testing) of OWC wave energy devices, plant control, and monitoring and overall device performance.

INETI actively participated in the studies for the development of the Pico pilot plant including monitoring. Among the participation in JOULE projects on wave energy, INETI co-ordinated the WERATLAS - European Wave Energy Atlas project and developed ONDATLAS - a nearshore wave atlas for Portugal.

WEC – Wave Energy Centre, Portugal

The Wave Energy Centre (WEC) was established in March 2003 as a non-profit organization consisting of companies and R&D institutions.

The objectives of the Wave Energy Centre are to assist its members in developing wave energy technology namely by promoting, managing and developing projects, training scientists and technicians, and information dissemination to the public.

Staff of this Centre has previous experience in various areas of wave energy utilization including design, hydrodynamic, wave-to-wire modelling and control and also on wave energy economics.

Figure 12 | WERATLAS

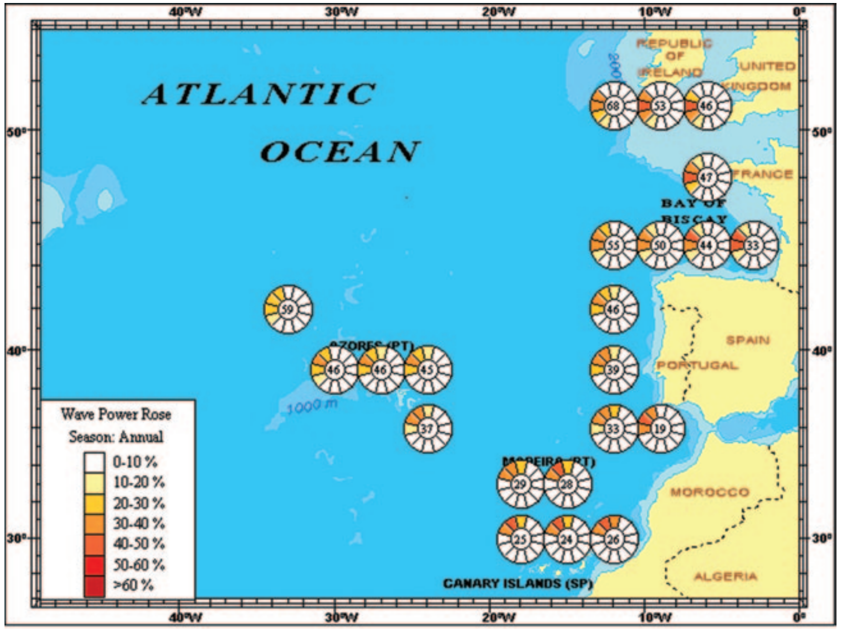

Figure 13 | Tank testing of the PS Frog Mk 5 (Lancaster University)

The Robert Gordon University, UK

The activity focus of The Robert Gordon University is primarily research of the extraction of energy from tidal currents and ocean waves, in particular, the group research is directed towards understanding the interactions between the energy extraction technology and the environment. Prior experience in ocean energy research was devoted to the following projects:

> Optimising the Performance of Tidal Current Turbines;
> Optimisation of Tidal Farms;
> Tidal Current Resource Assessment and Associated Parametric Design and Implementation Plan for the Pentland Firth;
> Hydrodynamic Modelling of Yell Sound in Shetland;
> Environmental Impacts from Tidal Stream Developments;
> Market Survey into the Development Potential for Tidal Current Power;
> Prototype Support Structure for Sea Bed Mounted Tidal Current Turbines;
> Development of a Tidal Hydrogen Generation System joint with the University of St Andrews;
> Supergen Marine Energy Consortium with the University of Edinburgh, Heriot-Watt University and the University of Lancaster

The most fundamental research being conducted relates to assessing the impact of energy extraction upon the nature of regional and amphidromic tidal environments. This work is being conducted in parallel with an assessment of the importance of coherent turbulence and eddy lock-in upon the design of extended tidal current energy devices and support structures.

Lancaster University, UK

The Engineering Department at Lancaster has been engaged in wave power research continuously since 1976. A number of devices have been invented and investigated in Lancaster

University. These have included the Lancaster Bag, Frog and Frond. The latest design, PS Frog Mk 5, promises increased energy capture and reduced costs.

Besides the work on devices, generic research into the theory of Wave Energy Converters and their systematic design has been carried out leading to the identification of promising devices for wave energy conversion. Accepting the view that the most promising form was a tuned point absorber, the crucial problem of providing a reaction to the wave force has been addressed, opting for an integral mass-spring system with the advantage of no external working parts. Specific attention has been paid to the task of keeping the device in resonance, essential to economical power capture.

Edinburgh University, UK

The activity focus of the Edinburgh University is the Engineering design and testing of wave and tidal stream energy devices. The Wave Power Group has been researching wave energy since 1974, and has more recently begun to develop ideas for tidal stream energy devices. Significant projects include the development of the "Duck" wave energy device, the Sloped IPS Buoy wave energy device and a novel tidal current rotor.

The group has a new Curved Wave Tank that was finished in June 2002. This tank is primarily designed for testing solo wave energy devices. Absorbing-wavemaker paddles are arranged in a 90-degree arc rather than in a linear array so as to increase the angular spread of fully realistic three-dimensional sea-states and to reduce long period cross-tank "seiche" waves. Compact beach modules based on an improved design have been installed along one side of the tank.

The group has recently constructed a 360-Degree Flow Table with Control of Velocity Gradient to investigate wave current interactions.

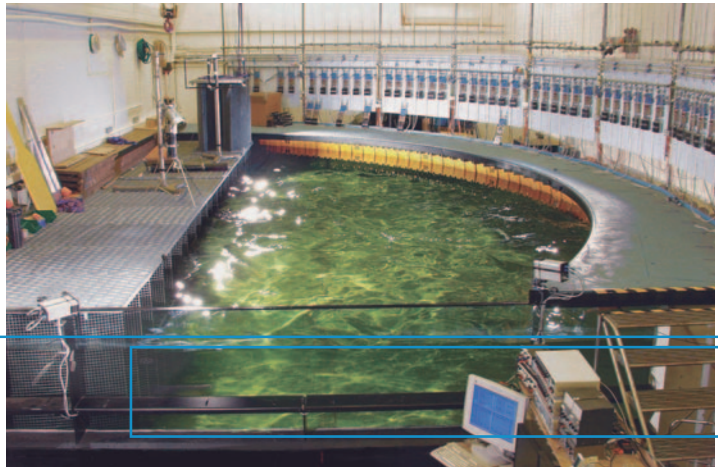

Figure 14 | Curved Wave Tank for testing solo wave energy devices (Edinburgh University)

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COUNTRY	ORGANISATION	NAME OF DEVICE	TYPE OF DEVICE
CANADA	Energetech www.energetech.com.au	Energetech Wave Energy System	Oscillating water column wave energy device
	AquaEnergy Canada, Ltd. (Wholly owned subsidiary of AquaEnergy Group Ltd., USA) http://www.aquaenergygroup.com	AquaBuOY	Slack-moored buoy
	Blue Energy Canada Inc. http://www.bluenergy.com	Davis Turbine	Ocean currents and tides converter
DENMARK	Wave Dragon ApS/Ltd www.wavedragon.net	Wave Dragon	Overtopping wave energy device
	Wave Star Energy A/S www.wave-star-energy.com	Wave Star	Multiple Point Absorbers
	Wave Plane International A/S www.waveplane.com	WavePlane	Overtopping wave energy device
IRELAND	Hydam Technology Ltd.	McCabe Wave Pump	Offshore floating wave device
	Clearpower	Wavebob	Offshore wave energy device
PORTUGAL	OCEANERGIA	AWS-Archimedes Wave Swing	Offshore submerged wave energy device
	ENERWAVE – Produção de Energia, Lda	VIPRE device	Overtopping shoreline wave energy device
UNITED KINGDOM	Wavegen www.wavegen.com	LIMPET	Shoreline oscillating water column wave energy device
	Tidal Energy Business www.tidal-eb.co.uk	Stingray	Tidal stream
	The Engineering Business Ltd www.engb.com	EB Frond	Seabed mounted nearshore wave energy device
	Marine Current Turbines Limited www.marineturbines.com	SeaGen	Tidal turbine
	Ocean Power Delivery Ltd www.oceanpd.com	Pelamis	Floating offshore attenuator
	QinetiQ www.QinetiQ.com	Cycloidal Tidal Stream Generator	Tidal stream
	SMD www.smd-uk.com	TidEl	Tidal stream
	Tidal Hydraulic Generators Ltd www.europus.com	Tidal Stream Generator	Multi turbines on common a frame with no seabed foundations

Table 5 | Organisations to commercialise Ocean Energy Systems

Overview of Commercialisation

In the last years emerging companies have been deeply involved in the development of wave and marine current energy devices and are progressing with their first demonstration plants. However Ocean Energy Conversion has still to face greater technical challenges that require continuation of research and development to a significant extent. Some concepts have already demonstrated their operability but there is a need for these technologies to demonstrate long-term performance and reliability, and cost reduction to prove commercially.

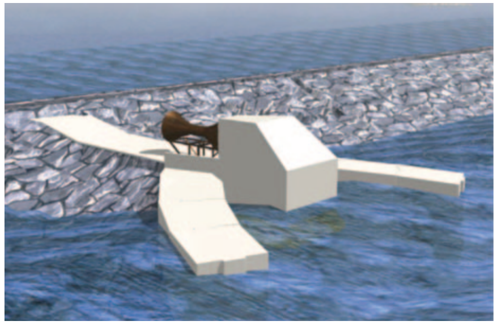
The companies that exist in the Member Countries to develop and commercialise ocean energy systems, the type of technology and the development status are briefly presented below.

Status of device/project development by companies involved in Ocean Energy:

Energetech Wave Energy System > First full-scale demonstration plant to be commissioned by year-end 2004 near Sydney, Australia. A 2 MW plant is being planned to be sited on Vancouver Island.

AquaBuOY > AquaEnergy Canada, a subsidiary of AquaEnergy Group Ltd., has proposed a project to pre-commercially demonstrate a 250 kW AquaBuOY in British Columbia. Once the technology is demonstrated, AquaEnergy Canada plans to develop a 5 MW commercial offshore wave energy plant in British Columbia.

Davis Turbine	>	The technology has completed the proof of concept with six working prototypes and has achieved commercial extraction efficiencies. Blue Energy Canada is in the process of funding a 500 kW commercial demonstration project.
Wave Dragon	>	Prototype testing at 1:4.5 scale started in 2003. Verification of wave energy absorption and power take-off efficiency predictions continues throughout 2004.
Wave Star	>	Successful 1:40 scale tank test done in 2001. Design of 5 MW system in progress, scaled down to 1:10 for sea trials.
WavePlane	>	Model testing and small-scale open sea tests.
AWS-Archimedes Wave Swing	>	2MW built and ready to be deployed offshore Portugal.



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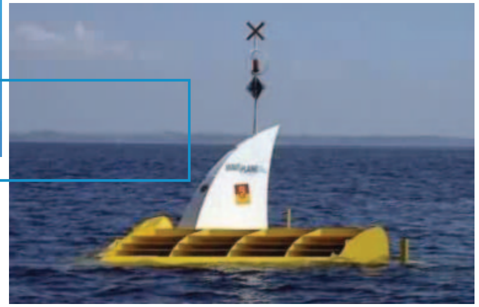

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Figure 15 | Port Kembla Wave Energy Project (Energetech)

Figure 16 | The AquaBuOY (AquaEnergy Group Ltd)

Figure 17 | Wave Dragon prototype in Nissum Bredding, Denmark (courtesy of Wave Dragon Aps)

Figure 18 | WavePlane in the sea (courtesy of Wave Plane International A/S)

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Figure 19 | The 2MW AWS device (courtesy of Teamwork Technology)

Figure 20 | Limpet power plant (Wavegen)

VIPRE device	>	Small scale (1:20) model testing in wave tank.
LIMPET	>	Demonstration shoreline plant operating in Scotland on the island of Islay since late 2000. Commercial opportunities for shoreline and near shore OWC plant now being developed. Floating options under development.
Stingray	>	Full-scale 150kW demonstrator has been operated in Yell Sound (the Shetland Islands, Scotland) during 2002 and 2003. Analysis of results is progressing.
EB Frond	>	Small-scale (1/25) model testing is underway, with the intention of moving on to intermediate-scale (1/5) testing.
SeaGen	>	First full scale prototype device installed off the north coast of Devon, and work is progressing with the second commercial scale, grid connected prototype unit.

Pelamis	>	Building of first full-scale (750kW), pre-production prototype was nearing completion for tests at the European Marine Energy Centre (EMEC), Orkney during 2004.
Cycloidal Tidal Stream Generator	>	Initial feasibility study of generator concept.
TidEl	>	Small-scale (1/10) model being tested at the New and Renewable Energy Center at Blyth.
Tidal Stream Generator	>	The single turbine prototype was built and tested in a tidal stream in 2002. A modular frame design concept, rotating turbine pedestal design and installation and lifting technique has been completed in December 2003. Detail optimisation /design for the manufacture of the frame and turbines for installing in a 3m/s flow is planned to commence in February 2004.


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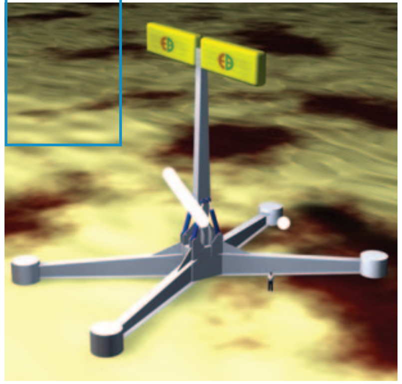
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Figure 21 | Stingray in Yell Sound, Shetland Islands, Scotland (Tidal Energy Business)

Figure 22 | Preliminary Concept of the EB FROND (courtesy of Engineering Business Ltd)

Figure 23 | The Pelamis first full-scale being towed from Rosyth to Leith Docks, Edinburgh (Ocean Power Delivery Ltd)

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