European Thematic Network on Wave Energy

Wave energy Utilization in Europe

Current Status and Perspectives

EESD

E E S D

Wave energy is an abundant renewable resource, which is starting to be exploited by several European countries. Considerable progress has been made over the past decade in this sector in Europe, resulting in some technologies being at, or near, commercialization; others still require further R&D. R&D is being supported by national Programmes and the Programmes for Research, Technological Development and Demonstration of the European Commission, which have stimulated coordinated working in this field among the European countries and have significantly contributed to the progress in wave energy utilization in Europe.

An important step to co-ordinate collaboration between European countries in the wave energy sector has been taken through the formation of the **"European Thematic Network on Wave Energy".** The Network was launched in 2000 with participation of 14 wave energy representatives from various European countries in the frame of the Fifth Framework Programme for Research, technological Development and Demonstration of the European Commission. Its main targets are the co-ordination and the improvement of the interactions between major players in wave energy and the establishment of industrial confidence in emerging wave energy conversion technologies.

This publication, produced in the framework of the promotional activities of the **"European Thematic Network on Wave Energy"**, renders the current status of wave energy utilization in Europe and highlights the potential for innovative wave energy technologies to become widely applied and contribute superior services to the citizen. Particular reference is made to the structure, the objectives and the anticipated results of the network.

Along with the other promotional activities of the network, which include publications in international journals, the establishment of an internet website and the support of seminars and conferences, this brochure intends to raise the profile and general understanding of wave energy by a range of target groups in Europe, like the general public, potential investors, planners and electricity utilities.

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Contents

Preface

The world energy consumption is estimated to rise considerably over the next decades and in the same period the energy consumption in the European Union will increase by almost a similar amount. Being constantly reminded that traditional methods of energy production are contributing to serious environmental problems the governments of the Member States have seen the urgent need for pollution-free power generation. The energy sector was forced through a renovating process, which sees its opening towards renewable energy. In the dynamic evolution of the renewable energy industry a wave energy industry is emerging. Although the technology is relatively new and currently not economically competitive with more mature technologies such as wind energy, the interest from governments and industry is steadily increasing. An important feature of sea waves is their high energy density, which is the highest among the renewable energy sources.

The idea of converting the energy of ocean surface waves into useful energy forms is not new. There are techniques that were first patented as early as 1799 (Girard & Son, France), and, in addition, references in the technical literature to ideas that prescribe these techniques.

The intensive research and development study of wave energy conversion began however after the dramatic increase in oil prices in 1973. Different European countries with exploitable wave power resources considered wave energy as a possible source of power supply and introduced support measures and related programmes for wave energy. Several research programs with government and private support started thenceforth, mainly in Denmark, Ireland, Norway, Portugal, Sweden and the United Kingdom, aiming at developing industrially exploitable wave power conversion technologies in the medium and long term.

The amount of the R&D work on wave energy is very large and extensive reviews have been made e.g by Leishman & Scobie[1], Lewis[2], Salter[3], Thorpe[4], Ross[5], Petroncini[6], Clément et al.[7] and others.

The efforts in research and development in wave energy conversion have met the support of the European Commission, which has been since 1986 observing the evolution in the wave energy field. The research programmes of the Commission on wave energy effectively started with the 4th Framework Programme in 1994 following successful completion of related studies and preparatory RTD work. Two studies have set the basis on the potential to extract energy from sea waves and sea currents, the "Atlas of Wave Energy Resource in Europe" (1996) and the "Exploitation of tidal and marine currents" (1996).

It has been clear from the start that extracting power from the sea will be difficult. Experiences around the world have shown it. The Commission has therefore considered helping the development of the technology by financing projects making steps towards proving the technical feasibility of this energy extraction. The project selection was done on the basis on specific evaluation criteria and also in the demonstration by the consortium of their understanding of the difficulties. This approach provided two outstanding results, the Pico and the Limpet Pilot Plants, now in operation.

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1 Leishman, J.M & Scobie, G. (1976),"The development of wave power - a techno economical study", Dept. of Industry, NEL Report, EAU M25

2 Lewis, T., (1985), "Wave Energy - Evaluation for C.E.C", EUR9827EN

3 Salter, S.H. (1989). "World progress in wave energy - 1988". The international Journal of Ambient Energy. Vol. 10 (1)

4 Thorpe, T.W., (1992), "A Review of Wave Energy", ETSU-R-72

5 Ross, D., (1995), "Power from the Waves", Oxford University Press (pub.)

6 Petroncini, S., (2000), "Introducing Wave Energy into the Renewable Energy Marketplace", Msc Thesis, University of Edinburgh, UK

7 Clément A.H., McCullen,P., Falcão A., Fiorentino, A., Gardner, F., Hammarlund, K., Lemonis, G., Lewis, T., Nielsen, K., Petroncini, S., Pontes, M.-T., Schild, P., Sjöström, B.O., Sørensen H. C., Thorpe, T. (2002) "Wave Energy in Europe - Current Status and Perspectives", Renewable and Sustainable Energy Reviews **6**, pp. 405-431.

From 1993 the Commission supported a series of international conferences on wave energy (Edinburgh, UK, 1993, Lisbon, Portugal, 1995, Patras, Greece, 1998 and Aalborg, Denmark, 2000), which significantly contributed to the stimulation and coordination of the activities carried out throughout Europe within universities, national research centres and industry.

In the last twenty-five years wave energy has gone through a cyclic process of phases of enthusiasm, disappointment and reconsideration. However, the persistent efforts in R&D and the experience accumulated during the past years have constantly improved the performance of wave power techniques and have led today wave energy closer to commercial exploitation than ever before. Different schemes have proven their applicability in large scale under hard operational conditions, and a number of commercial plants are currently being built in Europe, Asia, Australia and elsewhere. Other devices are in the final stage of their R&D phase with certain prospects for successful implementation. Nevertheless, extensive R&D work is continuously required, at both fundamental and application level, in order to improve steadily the performance of wave power conversion technologies and to establish their competitiveness in the global energy market.

Wave Energy Resource

Among different types of ocean waves, wind generated waves have the highest energy concentration. Wind waves are derived from the winds as they blow across the oceans. This energy transfer provides a natural storage of wind energy in the water near the free surface. Once created, wind waves can travel thousands of kilometres with little energy losses, unless they encounter head winds. Nearer the coastline the wave energy intensity decreases due to interaction with the seabed. Energy dissipation near shore can be compensated by natural phenomena as refraction or reflection, leading to energy concentration ("hot spots").

The power in a wave is proportional to the square of the amplitude and to the period of the motion. Long period (~7-10 s), large amplitude (~2 m) waves have energy fluxes commonly exceeding 40-50 kW per meter width of oncoming wave. As most forms of renewables, wave energy is unevenly distributed over the globe. Increased wave activity is found between the latitudes of ~30° and ~60° on both hemispheres, induced by the prevailing western winds (Westerlies) blowing in these regions.

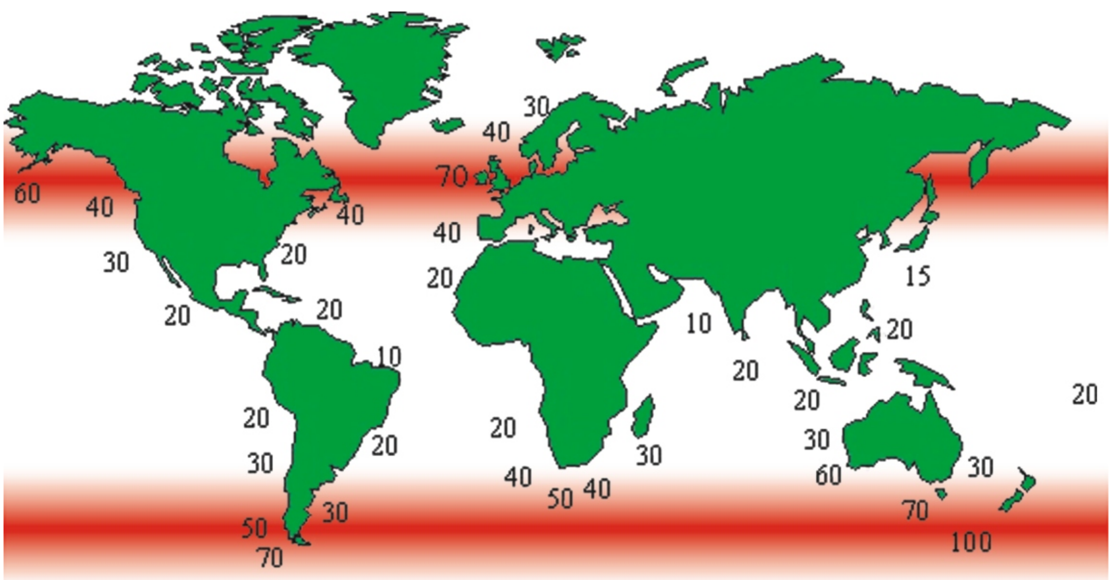

Figure 1: Global wave power distribution in kW/m of crest length

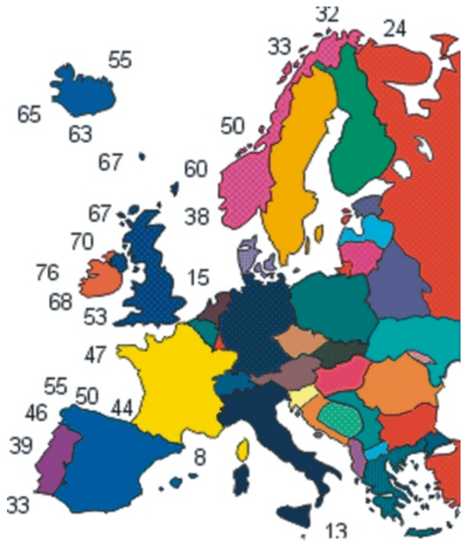

Figure 2: Wave power levels in kW/m of crest length in European waters.

Situated at the end of the long fetch of the Atlantic, the wave climate along the western coast of Europe is highly energetic. Higher wave power levels are found only in the southern parts of South America and in the Antipodes (Fig. 1). Recent studies[8] assign for the area of the north-eastern Atlantic (including the North Sea) available wave power resource of about 290 GW. The long-term annual wave power level increases from about 25 kW/m off the southernmost part of Europe's Atlantic coastline (Canary Islands) up to 75 kW/m off Ireland and Scotland (Fig. 2). In the North Sea, the resource changes significantly, varying from 21 kW/m in the most exposed (northern) area to about the half of that value in the more sheltered (southern) area. In the Mediterranean basin, the annual power level off the coasts of the European countries varies between 4 and 11 kW/m, the highest values occurring for the area of the south-western Aegean Sea. The entire annual deep-water resource along the European coasts in the Mediterranean is of the order of 30 GW, the total wave energy resource for Europe resulting thus to 320 GW.

8 Pontes, M.T., Athanassoulis, G.A., Barstow, S., Bertotti, L., Cavaleri, L., Holmes, B., Molisson, D. & Oliveira-Pires, H. (1998), "The European Wave Energy Resource", 3rd European Wave Energy Conference, Patras, Greece

General Aspects in the Utilization of Wave Energy

It is important to appreciate the difficulties facing wave power developments, the most important of which are:

- Irregularity in wave amplitude, phase and direction; it is difficult to obtain maximum efficiency of a device over the entire range of excitation frequencies
- The structural loading in the event of extreme weather conditions, such as hurricanes, may be as high as 100 times the average loading
- The coupling of the irregular, slow motion (frequency ~0.1 Hz) of a wave to electrical generators requires typically ~500 times greater frequency.

Obviously the design of a wave power converter has to be highly sophisticated to be operationally efficient and reliable on the one hand, and economically feasible on the other. As with all renewables, the available resource and variability at the installation site has to be determined first. The above constraints imply comparably high construction costs and possibly reduced survivability, which, together with misinformation and lack of understanding of wave energy by the industry, government and public, have often slowed down wave energy development.

On the other hand, the advantages of wave energy are obvious, the development of which is in line with sustainable development as it combines crucial economic, environmental and social factors. Wave energy is generally considered to provide a clean source of renewable energy, with limited negative environmental impacts. In particular, wave power is seen as a large source of energy not involving large CO_2 emissions.

Thorpe[9] summarizes the environmental impacts of wave energy conversion technologies as depicted in the following table.

Table 1: Environmental impact of wave energy devices

Environmental Effects	Shoreline	Nearshore	Offshore
Land use/sterilization	L		
Construction/maintenance sites	L		
Recreation	L	L	
Coastal erosion	L	L-M	L-M
Sedimentary flow patterns		L	L
Navigation hazard		L	L
Fish & marine biota	L	L	L
Acoustic noise	L		
Working fluid losses		L	L
Endangered species	L	L	
Device/mooring damage		L-M	L-M

(L: Low, M: medium)

The abundant resource and the high-energy fluxes of wave power prescribe - at appropriate design of the devices - economically viable energy production. Particular advantages of wave energy are the limited environmental impact, the natural seasonal variability of wave energy, which follows the electricity demand in temperate climates, and the introduction of synchronous generators for reactive power control. The negligible demand of land use is also an important aspect, followed by the current trends of offshore wind energy exploitation. As for most renewables, the in-situ exploitation of wave energy implies diversification of employment and security of energy supply in remote regions. Furthermore, the large-scale implementation of wave power technologies will stimulate declining industries, as e.g. shipbuilding, and promote job creation in small and medium-sized enterprises.

9 Thorpe, T.W., (1992), "A Review of Wave Energy", ETSU-R-72

The Current Status of Wave Energy Technologies

Economical Status

In the last five years there has been a resurgent interest in wave energy. Nascent wave energy companies have been highly involved in the development of new wave energy technologies such as the Pelamis, the Archimedes Wave Swing and the Limpet. At present the world-installed capacity is about 2 MW mainly from demonstration projects.

The potential world-wide wave energy economic contribution in the electricity market is estimated of the order of 2,000 TWh/year, about 10% of the world electricity consumption, and with an investment cost of EUR 820 billion[10]. The predicted electricity generating costs from wave energy converter have shown a significant improvement in the last twenty years, which has reached an average price of approx. 0.08 EUR/kWh at a discount rate of 8%. Compared to the average electricity price in the EU, which is approx. 0.04 EUR/kWh, electricity price produced from wave energy is still high, but is forecasted to decrease with the development of the technology. This can be speeded up with initial financial and market support as it has been made in the past for preceding technologies such as wind, nuclear and oil.

The assessment of the commercial prospects for wave energy is difficult, because estimates of the cost of power from wave energy devices represent a snapshot of the status and costs of evolving designs at their current stages of their development. The electricity costs of a number of devices have been evaluated over the past 10 years using a peer-reviewed methodology[11].

[10] Thorpe, T.W., (1999),"An Overview of Wave Energy Technologies: Status, Performance and Costs", "Wave Power - Moving Towards Commercial Viability", IMECHE Seminar, London, UK

[11] Thorpe, T.W.,(1999), "A brief review of wave energy", Report ETSU-R-120 for the DTI, AEA Technology.

The plot of Fig. 3 of the resulting costs against the year in which the design of a device was completed shows a significant reduction in generating costs. At best, this is similar to improvement of generating costs for wind turbines, so that there are now several wave energy devices with predicted costs of about 8,5 cEUR/kWh or less at 8% discount rate, if the devices achieve their anticipated performance.

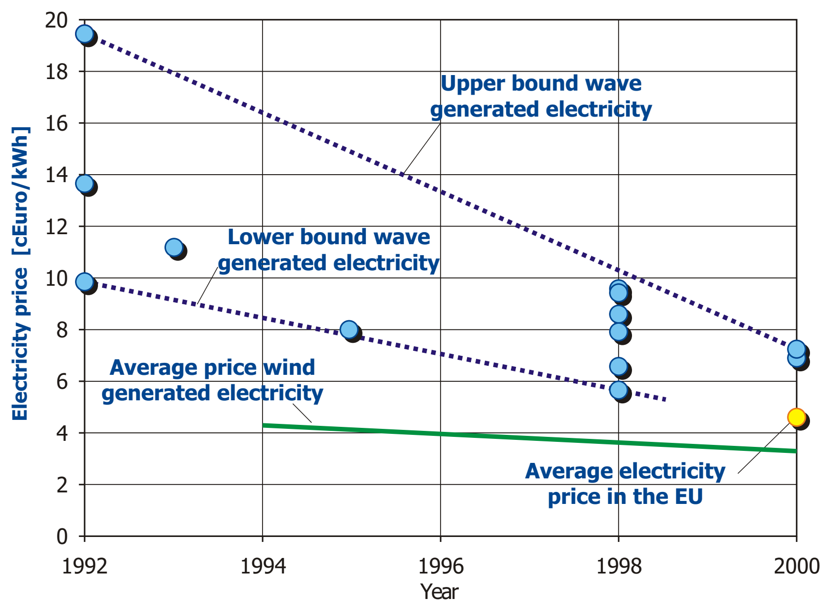

Figure 3: Predicted electricity costs for wave energy technologies

There are well advanced plans to increase the wave energy capacity in the rest of the world to over 15 MW in the next few years. Further predictions for future world-wide capacity are, at present, speculative but several companies have plans for the deployment of several MWs per year in the period 2003-2005. An independent assessment of the likely markets indicated that, if the wave energy devices perform as predicted, then their economic contribution would be over 2000 TWh/year by the year 2025. This is comparable to the amount of electricity currently produced world-wide by large scale hydroelectric schemes and would correspond to a capital investment of over € 800 billion.

Technological Status

The amount of ongoing work on wave energy technologies is large, and cannot be done justice in a single presentation. Although early RTD programmes on wave energy considered designs of several MW output power, recent designs are rated at power levels ranging from a few kW up to 2-4 MW. Massive power production can be achieved by interconnection of large numbers of devices.

In contrast to other renewables the number of concepts for wave energy conversion is very large; however, they can be classified within a few basic generic techniques. Here, some representative and promising technologies will be presented. For more detailed information the reader may refer to Lewis[12], Thorpe[13] and Clément et al.[14]. For ease of presentation the devices are categorised according to the distance of the location of installation from the shore, i.e. in shoreline, near shore and offshore devices.

Shoreline Devices

Shoreline devices are fixed to or embedded in the shoreline. This has the advantage of easier installation and maintenance. In addition shoreline devices would not require deep-water moorings or long lengths of underwater electrical cable. However, they would experience a much less powerful wave regime. This could be partially compensated by natural energy concentration ("hot spots"). Furthermore, the deployment of such schemes could be limited by requirements for shoreline geology, tidal range, preservation of coastal scenery etc.

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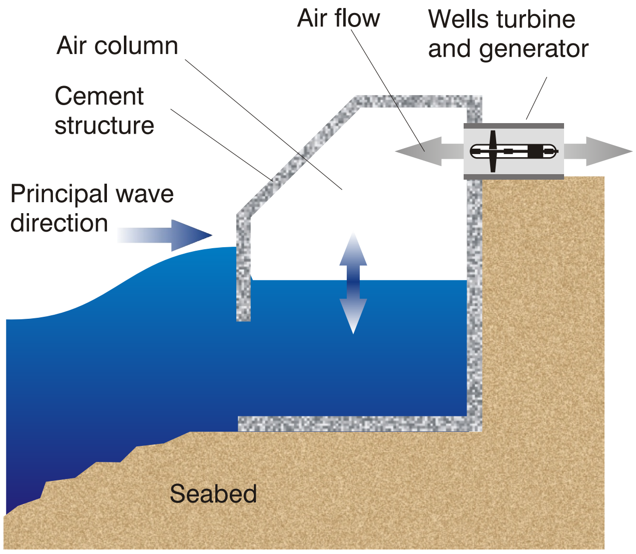
[12] Lewis, T., (1985), "Wave Energy - Evaluation for C.E.C", EUR9827EN

[13] Thorpe, T.W., (1992), "A Review of Wave Energy", ETSU-R-72

[14] Clément A.H., McCullen,P., Falcão A., Fiorentino, A., Gardner, F., Hammarlund, K., Lemonis, G., Lewis, T., Nielsen, K., Petroncini, S., Pontes, M.-T., Schild, P., Sjöström, B.iO., Sørensen H. C., Thorpe, T. (2002) "Wave Energy in Europe - Current Status and Perspectives", Renewable and Sustainable Energy Reviews **6**, pp. 405-431.



One major class of shoreline devices is the oscillating water column (OWC). It consists of a partially submerged, hollow structure, which is open to the seabed below the waterline. The heave motion of the sea surface alternatively pressurizes and depressurizes the air inside the structure generating a reci-procating flow through a "Wells"-turbine which is installed beneath the roof of the device. A "Wells"-turbine, named after its inventor, Prof. Alan Wells, is a special type of turbine, capable of maintaining constant direction of revolution despite the direction of the air flow passing through it. Two of the OWC wave power plants developed in Europe are the following:

The **European Pilot Plant**[15,16], on the Pico Island in the Azores is a 400 kW OWC developed by a European team coordinated by Instituto Superior Tecnico (Portugal), consisting of six Portuguese partners and two partners from the United Kingdom and Ireland. The plant was designed as full-scale testing facility, it is fully automated and it supplies a sizable part of the island's energy demand.

The **LIMPET**[17,18], is a 500 kW OWC developed by the Queen's University of Belfast and Wavegen Ltd in the United Kingdom. A 75 kW prototype was constructed on the island of Islay, Scotland in 1991. The LIMPET OWC is the successor of this prototype, intended to address many of the issues currently hindering the full-scale deployment of OWC devices.

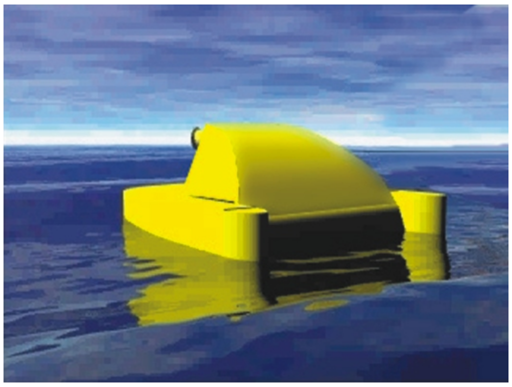
[15] Falcão, A.F. de O. (2000). "The shoreline OWC wave power plant at the Azores", 4th European Wave Energy Conference, Aalborg, Denmark.

[16] falcao@hidro1.ist.utl.pt

[17] Heath, T., Whittaker, T.J.T. & Boake, C.B. (2000). "The design, construction and operation of the LIMPET wave energy converter (Islay Scotland). 4th European Wave Energy Conference, Aalborg, Denmark

[18] http://www.wavegen.com

Near-Shore Devices



The main prototype device for moderate water depths (i.e up to ~20 m) is the **OSPREY**[19,20], developed by Wavegen Ltd. in the UK. It is designed for deployment on the seabed. A 2 MW prototype is planned, which will operate in 15m depth within 1 km from the shore.

Offshore Devices

This class of device exploits the more powerful wave regimes available in deep water (>40m depth). More recent designs for offshore devices concentrate on small, modular devices, yielding high power output when deployed in arrays. Some of the promising offshore WECs developed in Europe are the following:

The **Archimedes Wave Swing**[21,22], developed by Teamwork Technology BV, Netherlands; it consists of a hollow, pressurized structure, the upper part of which is initiated to heave motions by the periodic changing of hydrostatic pressure beneath a wave. A 2 MW pilot plant has been constructed and is waiting to be deployed Spring 2003 off the coast of Portugal.

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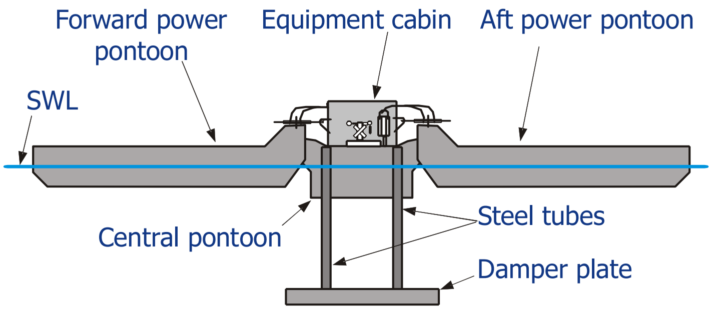
[19] Thorpe, T.. (1999). "An Overview of Wave Energy Technologies: Status, Performance and Costs". "Wave power - Moving towards commercial viability", IMECHE Seminar, London, UK

[20] http://www.wavegen.co.uk

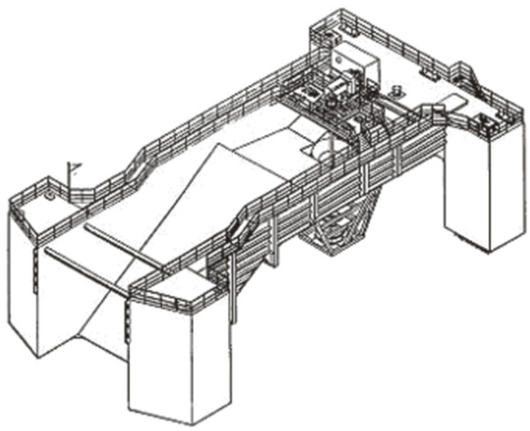
[21] Rademakers, L.W.M.M., van Schie, R.G., Schuttema, R., Vriesema, B. & Gardner, F. (1998) "Physical model testing for characterizing the AWS", 3rd European Wave Energy Conference, Patras, Greece

[22] http://www.waveswing.com



The **McCabe Wave Pump**[23,24], consists of three rectangular steel pontoons, which are hinged together across their beam. The bow of the fore pontoon is slack-moored and two more slack moorings are attached part way down the aft pontoon. This allows the system to vary its alignment in order to head into the oncoming seas. A 40 m long prototype was deployed in 1996 off the coast of Kilbaha, County Clare, Ireland.

The **Floating Wave Power Vessel**[25,26], is an overtopping device for offshore operation developed by Sea Power International, Sweden. It consists of a floating basin supported by ballast tanks in four sections. A patented anchor system allows the orientation of the vessel to the most energetic wave direction. A pilot plant has been developed and deployed in the '80s near Stockholm, Sweden while a 1.5 MW vessel is planned to be deployed at 50-80 m depth 500 m offshore Mu Mess, Shetland.



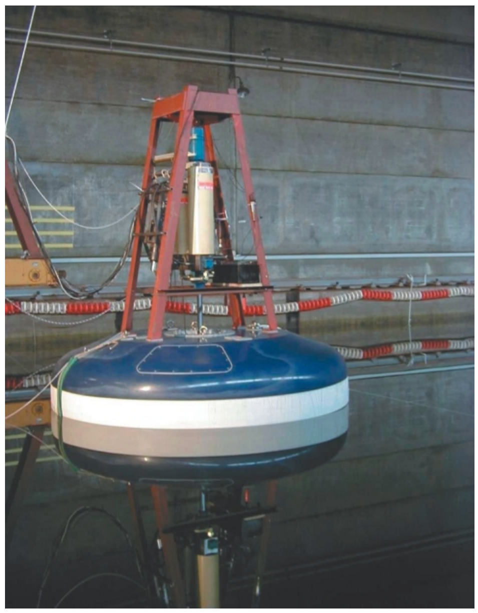
[23] Kraemer, D.R.B., Ohl, C.O.G. & McCormick, M.E. (2000). "Comparison of experimental and theoretical results of the motions of a McCabe wave pump", 4th European Wave Energy Conference, Aalborg, Denmark

[24] http://Wave-power.com

[25] Lagstroem, G.. (2000). "Sea Power International - Floating wave power vessel, FWPV". "Wave power - Moving towards commercial viability", 4th European Wave Energy Conference, Aalborg, Denmark

[26] http://www.seapower.se

The **Pelamis**[27,28], device is a semi-submerged articulated structure composed of cylindrical sections linked by hinged joints. The wave induced motion of these joints is resisted by hydraulic rams which pump high pressure oil through hydraulic motors via smoothing accumulators. A 130 m long and 3.5 m diameter device rated at 375 kW is being developed by Ocean Power Delivery Ltd - OPD, Scotland.



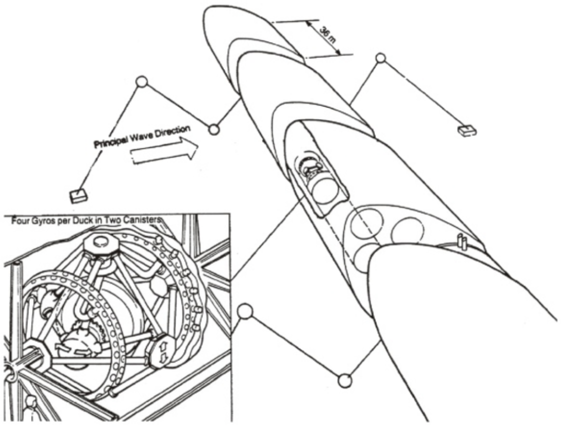
The **Point Absorber Wave Energy Converter**[29,30], developed by Rambøll in Denmark, consists of a float connected to a suction cup anchor by a polyester rope. The relative motion between the float on the sea surface and the seabed structure activates a piston pump (actuator) inserted between the rope and the float. A 1:10 scale model was tested at sea at the Danish test site "Nissum Bredning" over a period of three months, and a 1:4 scale model with 2.5 m diameter is currently developed for open sea testing.

[27] Yemm, R. (1999). "The history and status of the Pelamis Wave Energy Converter", "Wave power - Moving towards commercial viability", IMECHE Seminar, London, UK

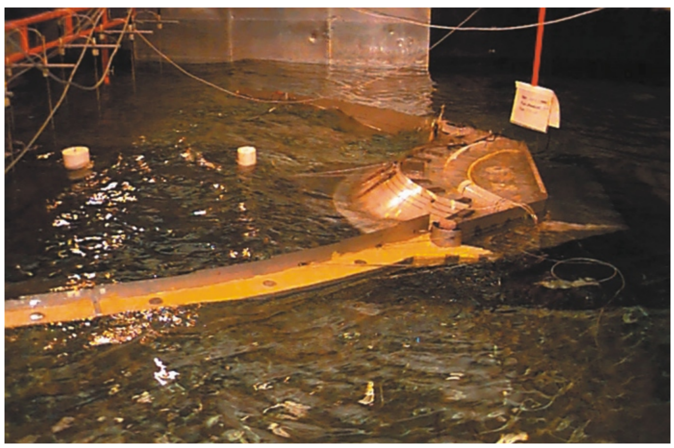
[28] http://www.oceanpd.com

[29] Nielsen, K. (2001). "Point absorber feasibility and development requirements", Technical Report, RAMBØLL

[30] http://www.waveenergy.dk



The concept of the **Salter Duck**[31] was introduced in 1974 by S. Salter[32]. An important feature of this device is the capability of converting both the kinetic and potential energies of the wave, achieving thus very high absorption efficiencies (theoretically over 90%). The system has undergone considerable development since 1983 and it was redesigned in 1993. The present design is characterized by high availability and overall efficiency and low energy production costs.



The **Wave Dragon**[33,34], is an offshore wave energy converter of the overtopping type developed by a group of companies leaded by Wave Dragon ApS, Denmark. It utilizes a patented wave reflector design to focus the wave towards a ramp and fill a higher-level reservoir. Electricity is produced by a set of low-head Kaplan turbines. The scheme has been tested in the laboratory at 1:50 scale and on a 1:3.5 scale model turbine. A 57 m wide and 261 tons heavy prototype in scale 1:4.5 rated in full scale to 4 MW is being deployed in Nissum Bredning, Denmark.

31 http://www.mech.ed.ac.uk/research/wavepower/index.htm

32 Salter, S.H. (1974). "Wave Power". Reprinted from Nature, Vol. 5459

33 Hald, T., Friis-Madsen, E. & Kofoed, J.P. (2002): "Hydraulic Behaviour of the Floating Wave Energy Converter Wave Dragon". 10th IMAM Conference, Greece

34 http://www.wavedragon.net

The European Wave Energy Network

Aim and Participants

An important step to co-ordinate collaboration between European countries in the wave energy sector has been taken in the formation of the "European Thematic Network on Wave Energy". In 1999, the European Commission invited 14 wave energy representatives from various European countries to co-operate in such a Network. The Network was launched in 2000 and its tasks address important scientific, technical and economic aspects in wave energy conversion:

Task	Main Task	Subtasks
A	Co-operation with power industry	• Development of power quality standards • Development of safety standards • Assessment of procedures, costs & facilities for power transmission
B	Social, planning & environmental impact	• Industrial benefit & job creation • Institutional barriers • Environmental impact • Planning considerations
C	Financing & economic issues	• Market status of wave energy • Economics of wave energy • Financing of wave energy projects • Environmental economics
D	R&D on wave energy devices	• Current & wave energy device status • R&D requirements for 1st, 2nd and 3rd generation devices • Tidal energy device status and R&D requirements • Strategy and action plan for R&D for current & wave energy devices
E	Generic technologies	• Plant control & power output prediction • Pant monitoring & performance assessment • Loads and survivability • Maintenance & reliability • Modelling & standardised design methods
F	Promotion of wave energy	• Support for wave energy "events" • Publications in international Journals • Dissemination of printed material • Development of a wave energy Internet site

The contributing organizations to the network are the following:

	Organization	Task Leader	Task Participant
1	AEA Technology plc.(*), United Kingdom	C	B, F
2	University College Cork, Ireland	D	F
3	Ramboll, Denmark	A	B, C
4	SPoK ApS, Denmark	B	A, C
5	INETI, Portugal	E	A, E
6	Chalmers University, Sweden		A, C
7	Teamwork Technology, the Netherlands		C
8	Centre for Renewable Energy Sources, Greece	F	A, B
9	Ponte di Archimede nello Stretto di Messina SpA, Italy		D, E
10	Edinburgh University, United Kingdom		D
11	Instituto Superior Tecnico, Portugal		D, E
12	Ecole Centrale de Nantes, France		E
13	ESB International, Ireland		A
14	Hammarlund Konsult, Sweden		B

(*) Project co-ordinator

The different workgroups in the network will produce a variety of outputs, as standards, recommendations & guidelines, software, R&D results, information material, etc.

These outputs will be made available to the relevant targets groups, as developers, operators, public bodies, financiers, planners, etc. by different means of dissemination, as publications, presentations in Conferences and a web-site developed in the course of the project. The objectives of the different task areas of the network are summarized in the next pages.

Task Objectives

Co-operation with Power Industry

The objectives of this task area have been both to promote co-operation with the electrical power industry and to build on the experience gained in electrical generation and transmission of other relevant industries (e.g. wind). The three sub-Tasks are:

- developing a standard for grid connection of wave power plants, via a workgroup consisting of members from wave energy R&D community, electricity utilities, wind power industry and European certification;
- developing a standard for the safety of wave power conversion systems, using a working group co-operating with electricity utilities, offshore industry and European certification bodies;
- assessing the procedures and facilities for the power transmission for offshore and near-shore devices, including reviewing of existing standards for underwater cabling, cost analyses, determining the permissions and safety precautions required, as well as evaluating alternative transmission methods.

Social & Environmental Impact, Planning Considerations

The aims of this task have been to identify the barriers (planning, legal, structural and environmental) to the development of wave energy, together with the social and environmental benefits (e.g. employment issues, emissions reductions) arising from expected deployment of wave energy schemes, leading to the development of recommendations and guidelines for such deployment. This has been undertaken by collating and reviewing the existing information, transferring experience from other, relevant industries (e.g. offshore wind) and comparing the various national and international rules and regulations, regarding deployment.

Financial & Economic Issues

The aims of this task have been to evaluate the financing, economics and monetary issues for developing wave energy schemes. This will include a review the various approaches used throughout Europe to support RES, an assessment of their applicability to wave energy and a study of the financing of current demonstration schemes. There will also be an independent evaluation of the likely generating costs of the leading devices to assist in establishing credibility in wave energy economics. This Task will also review the various approaches to integrating the environmental benefits and impacts of electricity generation and assess their potential effects on the economics of wave energy. A separate sub-task concerns the estimation of the 'externalities', i.e. the environmental costs, of wave power technologies, and the 'internalisation' of these costs.

Research & Development on Wave Energy Devices

The objectives of this task have been to identify the current status of device development, to determine the technical barriers to the commercial development of these devices, to develop a standard for assessment of existing and new devices; and to develop a Strategy and Action Plan for future development. This has been achieved by collating, reviewing and evaluating material from current and past EU funded projects, national programmes and industrial projects. This will be undertaken in conjunction with the "Cluster Co-ordinator" (with special reference to the European Pilot Plants) and will assess the devices as first, second and third generation devices. Based on the output from this review a strategy for development will be drawn up.

Generic Technologies

This task aims to co-ordinate activities on generic technology issues in order to facilitate the exchange of experience and the transfer of knowledge and to promote transfer of knowledge and technology from the offshore industry and coastal engineering. This has been achieved by promoting:

- information exchange and studies on plant control methods and related energy quality and power output prediction;
- development of monitoring methodologies for plant performance;
- establishment of design criteria based on measured data at existing power plants, other coastal structures and the offshore oil and gas industries;
- exchange of experience on: maintenance requirements; corrosion; wear of structure and components and failures in wave power plants, leading to recommendations for reliability improvements;
- development of hydrodynamic and power take-off modelling tools.

Promotion of Wave Energy

This task aims to promote wave energy as a renewable source of energy within the public and a range of institutions and organisations involved in wave energy developments, as electrical power companies, offshore industries, research institutions, financial bodies, governmental offices etc. The works carried out in this task involve:

- developing support materials for suitable events (e.g. device launches, conferences, exhibitions);
- publishing articles in renewable energy and energy-related journals;
- producing booklets and educational material on wave energy for a range of audiences;
- development of an Internet web site on wave energy[35], including the results of all Thematic Network Tasks.

[35] http://www.wave-energy.net

Related Web Addresses

http://europa.eu.int
Central website of the European Union

http://www.eufores.org
European Forum for Renewable Energy Sources, European Commission

http://www.wave-energy.net
European Wave Energy Network

http://www.cres.gr
Centre for Renewable Energy Sources, Greece

http://www.dti.gov.uk/renewable
Department for Trade and Industry (renewables webpage), United Kingdom

http://www.esbi.ie
ESB International, Ireland

http://www.etsu.com
ETSU, United Kingdom

http://www.iea-oceans.org
Implementing Agreement on Ocean Energy Systems (International Energy Agency)

http://www.ineti.pt
Instituto Nacional de Engenharia e Tecnologia Industrial

http://www.marineturbines.com
Marine Current Turbines Ltd, United Kingdom

http://www.mech.ed.ac.uk/research/wavepower/index.htm
University of Edinburgh (Wave Energy Group), United Kingdom

http://www.oceanpd.com
Ocean Power Delivery Ltd, United Kingdom

http://www.scottishrenewables.com
Scottish Renewables Forum, United Kingdom

http://www.spok.dk
Spok ApS /EMU Consult, Denmark

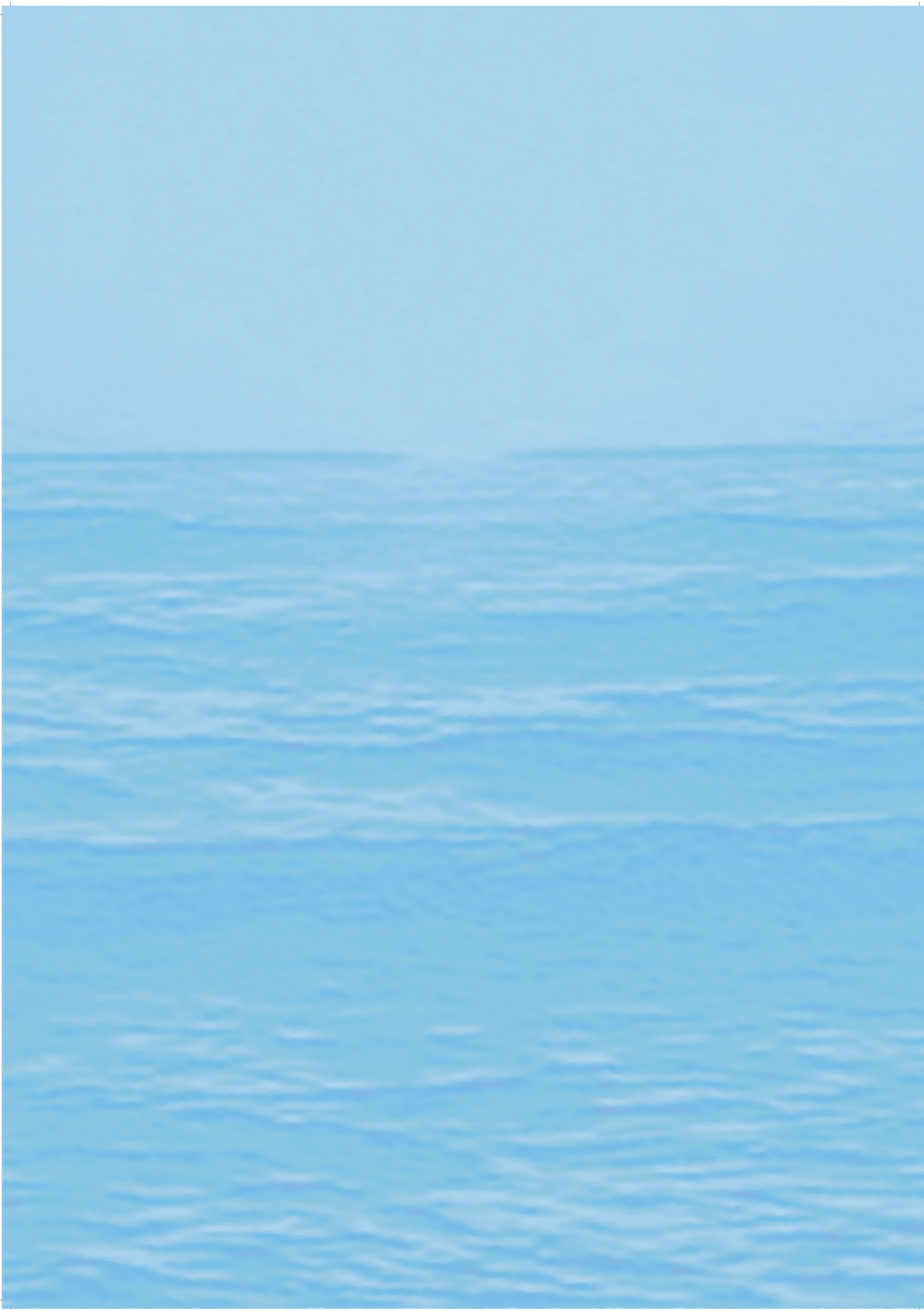
http://www.ucc.ie/ucc/research/hmrc/ewern.htm
Hydrodynamics and Maritime Research Centre, University College Cork, Ireland

http://www.wavedragon.net
Wavedragon ApS, Denmark

http://www.waveenergy.dk
Danish Wave Energy Association, Denmark

http://www.wavegen.co.uk
Wavegen Ltd., United Kingdom

http://www.waveswing.com
Teamwork Technology BV, the Netherlands



NOTICE TO THE READER

Extensive information on the European Union is available through the EUROPA service at internet website address http://europa.eu.int

The overall objective of the European Union's energy policy is to help ensure a sustainable energy system for Europe's citizens and businesses, by supporting and promoting secure energy supplies of high service quality at competitive prices and in an environmentally compatible way. The Research Directorate - General of the European Commission initiates, coordinates and manages energy policy actions at transnational level in the fields of solid fuels, oil & gas, electricity, nuclear energy, renewable energy sources and the efficient use of energy. The Directorate General's mission can be summarised as follows:

- to develop the European Union's policy in the field of research and technological development and thereby contribute to the international competitiveness of European industry;
- to coordinate European research activities with those carried out at the level of the Member States;
- to support the Union's policies in other fields such as environment, health, energy, regional development etc;
- to promote a better understanding of the role of science in modern societies and stimulate a public debate about research-related issues at European level.

Further information on activities of the Research DG is available at the internet website address
http://europa.eu.int/comm/dgs/research/index_en.htm

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