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Harnessing the Power of the Oceans

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Exploiting the energy of the oceans has for long attracted the talents of innovators. Today, concrete efforts are mobilising numerous technologies to exploit the world's vast ocean energy resources. The role of these technologies is set to grow steadily in the drive for reliable, cost-competitive and environmentally sound energy. The IEA Implementing Agreement on Ocean Energy Systems (IEA-OES) brings together a fast growing number of stakeholder countries to facilitate and co-ordinate ocean energy research, development, demonstration and wider market deployment.

Force and diversity

The oceans hold energy in numerous ways, so it is not surprising that many conversion technologies exist to exploit that energy. Broadly speaking, ocean renewable energy resources fall into five categories: tides, tidal (marine) currents, waves, temperature gradients and salinity gradients. What exactly is involved?

Tides. Potential energy linked to the force of tides can be harnessed by building fixed or floating barrages, or other types of construction, either at an estuary or offshore. Tidal energy is predominant in certain locations because those locations have unique geographic formations and strong tide conditions. When barrages are used, as the level of water rises and falls with the tides, a difference in water level develops on either side of the barrage and water is allowed to flow with the force of gravity through the barrage, thus turning turbines to produce power.

Tidal (marine) currents. Kinetic energy present in tidal (marine) currents can be turned into electricity by using modular turbine systems, which can be placed directly in-stream to generate power from the flow of water. The turbines can be either horizontal-axis or vertical-axis turbines (some are analogues to wind turbine systems), or of other sorts. These systems can be submerged or floating or fixed to the seabed.

[1] The IEA *OPEN Energy Technology Bulletin* is a web-based periodical newsletter published by the International Energy Agency (IEA).

Waves. Here, kinetic and potential energy created through ocean waves can be harnessed using modular technologies. These conversion systems operate through different methods of wave-device interaction (activated by movements like heave, pitch, or surge) and may need pneumatic, hydraulic or mechanical power take-off methods. The conversion system can be shore-based or floating, or semi-submerged or fully submerged. The wave-device interactions can create air flow to drive air turbines or water flow to drive water turbines; or they can exploit relative motion between bodies to drive hydraulic pumps and motors or mechanical gears, or they can activate direct generation systems.

Temperature gradients. Thermal energy created through temperature gradients between the warmer water at the sea's surface and the colder water deeper down can be harnessed using different ocean thermal energy conversion (OTEC) processes.

Salinity gradients. In places like the mouths of rivers, where there is a steady availability of both fresh water and sea water, the entropy of mixing water with different salt concentrations can be used to create power. It is called osmotic power. The pressure-retarded osmosis process is the most promising method for conversion of this energy.

Alongside these mainstream options, the energy of the oceans can also be used to produce drinking water, or compressed air and hydrogen for industrial applications. Also, aquaculture conditions can be improved using the oceans' own energy resources. Cold water near the sea-bed can be used for air conditioning. And integrating ocean energy with other renewable energy sources like offshore wind can optimise investment and improve the quality of the power supply.

In theory, the oceans could largely meet the world's energy needs in their totality. While the amount of renewable energy actually exploited will be a fraction of the resource levels theoretically available, the potential is nevertheless of the same order of magnitude as total electricity generation all around the world (18,235 TWh in 2005).

Theoretical tide and marine current resources represent estimated annual global potentials exceeding 300 TWh and 800 TWh per annum, respectively. For wave energy, the theoretical potential is estimated at between 8,000 TWh and 80,000 TWh per annum. These high potentials are attributable to the strong wind variations observed within the band between 30° and 60° latitude, and to the occurrence of circumpolar storms near the southern latitudes, which account for high-energy ocean waves in those areas. The global theoretical potential of ocean thermal gradients is estimated to be 10,000 TWh per annum. Significant temperature gradients in tropical coastal areas indicate good opportunities for OTEC within the Tropic of Capricorn and the Tropic of Cancer. The potential of salinity gradients is estimated at 2,000 TWh per annum.

Developing and deploying the technology

The different degrees of maturity of the various ocean renewable energy conversion technologies are shown in Figure 1. Tidal barrage plants are well advanced and a number of these, offering capacities of up to 240 MW, are operating on a commercial basis in various countries, notably Canada, China, France and Russia. Further new project initiatives for developments of this sort are in progress in China, the Republic of Korea, India, Mexico and the United Kingdom.

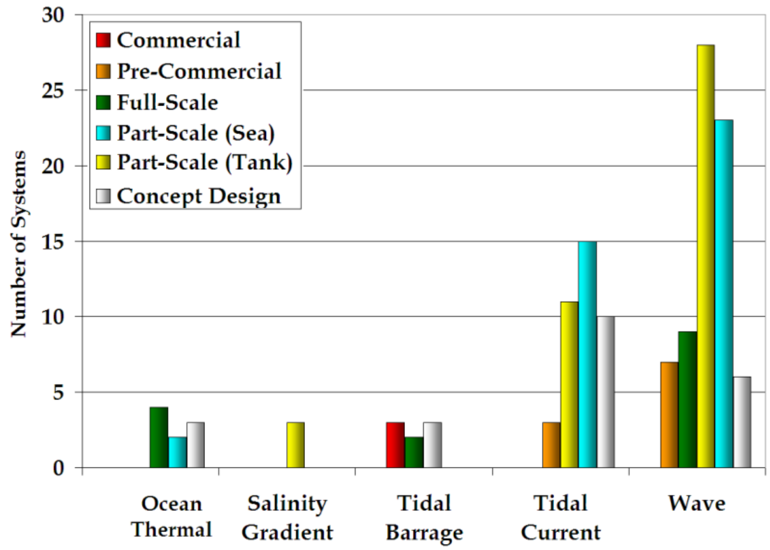

Figure 1 - Technology maturity of various ocean energy conversion systems

Information courtesy of Powertech Labs, Canada

Several wave and tidal current plants with capacities of up to 500 kW are now operational and connected to electrical grids. A number of pre-commercial projects in the range of 1 to 3 MW are awaiting deployment in various parts of the world. Some of these MW-size projects have been installed or are in process of installation. Two examples are shown in Figures 2 and 3, below.

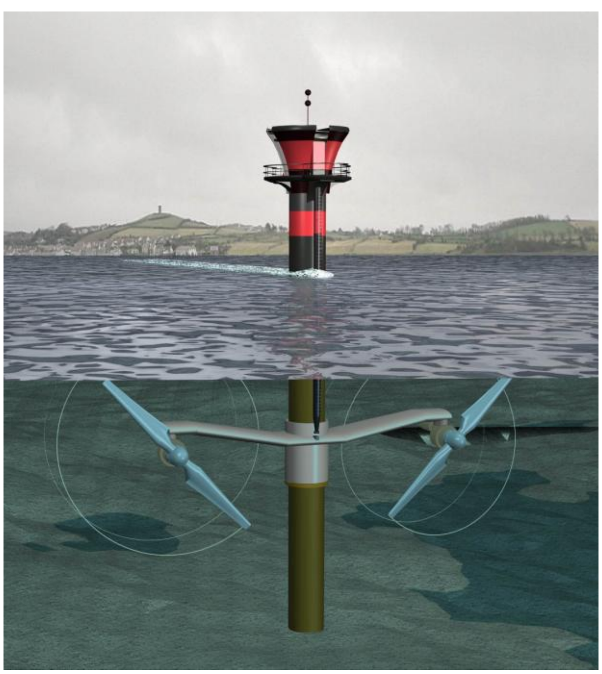

Figure 2 – Artist's impression of 1.2 MW twin-rotor tidal energy convertor, installed off the Northern Ireland coast

Courtesy of Marine Current Turbines Ltd.

Figure 3 - Pelamis wave energy devices (3 x 750 kW) in Leixoes harbour awaiting installation at Agucadoura (northern Portugal)

Photo courtesy of Enersis

Conversion technologies for harnessing energy associated with ocean thermal gradients and salinity gradients are at the research and development stage. India and Japan are very active in development of ocean thermal energy conversion (OTEC) and have built experimental plants up to 1 MW in size. As for osmosis through mixing water with different salt concentrations, companies in Norway and the Netherlands are working to develop technologies for harnessing osmotic power using pressure retarded osmosis. KW-size prototypes are expected to become operational in 2009. Full-scale demonstration and commercial production of salinity power is expected within 5-7 years.

A number of countries are exploring other ways to use ocean renewable energy resources for sustainable energisation of coastal and island communities. Areas of focus include not only generation of electricity but also the enabling of land-based or deepwater aquaculture and using the ocean as a heat pump for domestic heating and cooling, or production of drinking water through desalination. An example of successful application of this desalination technology is pictured in Figure 4. This 100 m3/day island-based low-temperature thermal desalination plant is now operational at Kavarati, India.

Figure 4 - 100,000 litres of drinking water are produced each day at this low-temperature thermal desalination plant in India

Photo courtesy of National Institute of Ocean Technology, Chennai, India

Creating the momentum

Today, more than 25 countries are involved in developing relevant conversion technologies for harnessing ocean renewable resources for electricity generation and/or other purposes. Figure 5 gives an idea of where the leading countries have embarked on research, demonstration and commercial operations.

Not all ocean energy conversion technologies are at the same stage of development. Indeed, some are quite new or only in their infancy compared to other renewables or conventional generation technologies. That is why a broad range of targeted national and regional policies is necessary to foster deployment of ocean energy world-wide and to exploit the huge opportunities that ocean energy offers. There are some tough challenges. For example, governments in more countries should shape energy policies for research, innovation and market deployment that encourage development of ocean energy technology, not least through market-based approaches. Complicated procedures for licensing and development permits need to be addressed. To assess performance, internationally recognised guidelines and standards are needed. Crucially, ease of access to the electrical grid has to be ensured.

Fortunately, several countries are already setting a good example by encouraging the development of ocean energy. A number of governments have implemented national policies for ocean energy and have adopted longer-term targets for deployment of ocean power. Also, several countries have taken specific measures to establish public demonstration infrastructure to facilitate development, demonstration and commercialisation of ocean energy technologies, and to address other regulatory and environmental issues.

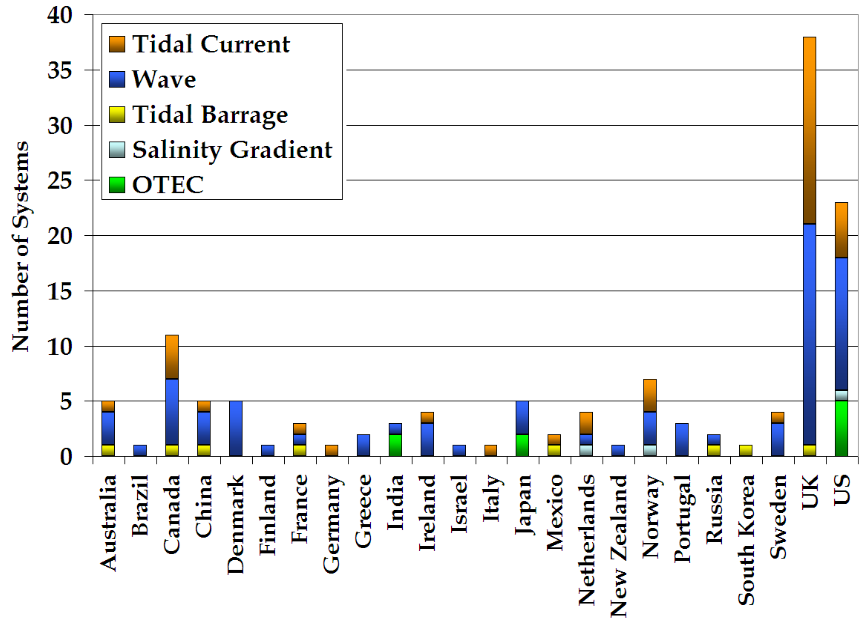

Figure 5: Ocean energy-related research, demonstration and commercial activities, as of December 2007

Information courtesy of Powertech Labs, Canada

The United Kingdom, for example, has adopted an energy policy designed to attract and support technology developers, including a programme for wave and marine-current energy development. At the end of 2007, the United Kingdom had by far the largest number of companies operating in this sector. In Ireland, a government strategy has been designed to accelerate development of wave energy through financial support for Irish technology developers. Three Irish companies have developed technologies that have advanced to the sea-tests phase. Portugal's strategy has created attractive conditions that facilitate the development of a wave energy industry, including feed-in tariffs and a large-scale pilot zone with simplified licensing procedures. Many technology developers have become interested in performing sea trials off Portugal's Atlantic coast.

Protecting the environment

Since we are still at an early stage in applying the technologies, information is limited regarding biophysical and socioeconomic environmental impacts of exploiting ocean renewable resources. Information is equally sparse on interaction between the conversion technologies and the environment. Several international initiatives are under way – notably within the IEA-OES programme – aimed at designing and conducting appropriate collaborative research to address knowledge gaps on some of the key environmental issues. Also, as with any environmental concern, a key approach is of course to engage local communities, the general public and other stakeholders in discussions and communication prior to commercial deployments of the technologies. In this way the opportunities, constraints and risks presented by ocean renewable energy resource in relation to sustainable economic development can be identified.

More concepts on the horizon

The ocean energy world is a fertile one for innovators. Noteworthy among the new concepts now being explored for harnessing tidal energy, we can point to those creating hydraulic heads (water pressure) or floating barrage-type constructions; double barrage concepts are being developed by various organisations.

As we have seen, a large number of wave and tidal-current conversion processes are still at the conceptual stage, including biomimetic conversion systems using devices whose forms imitate physical features of wildlife that has survived thousands of years in marine environments. Some of these conversion processes could play a major role in future advances with exploiting ocean energy.

In the field of aquaculture, another interesting concept uses ocean thermal energy conversion as the power source for a deepwater floating ocean nutrient enhancer.

IEA Ocean Energy Systems Implementing Agreement (IEA-OES)

The IEA-OES programme brings together countries determined to advance ocean energy research, development and demonstration through international co-operation and information exchange leading to the deployment and commercialisation of sustainable ocean energy technologies.

Current members are Belgium, Canada, Denmark, the European Commission, Germany, Ireland, Italy, Japan, Mexico, New Zealand, Norway, Portugal, Spain, United Kingdom and the United States.

Discussions regarding participation are under way with the governments of Australia, Brazil, China, Chile, France, India, the Netherlands, Republic of Korea, Russia, Sweden, and South Africa.

Visit the IEA-OES website.

Ocean renewable energy is an emerging resource option and no specific technologies have yet emerged as the definitive winners. We can therefore expect more conversion concepts to come onto the scene in future. Appropriate government action and public policy instruments will be necessary, however, if the truly vast opportunities for optimising the world's ocean renewable resources are to be seized without delay in the pursuit of more sustainable energy systems.