The Ocean Energy Report

Tidal
Wave
Ocean Thermal
Tidal or Marine Current
Salinity Gradient

Ed 4 2009

ABS Energy Research

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Introduction

The Mighty Whale, Pendulor, Pelamis, Tapchan, Wave Dragon, Stingray, Osprey, Limpet

The last two years have been eventful for ocean energy development, with several commercial "firsts", encouraging demonstration projects. The industry is now blazing the trail with the first commercial projects. The United Kingdom, specifically Scotland, is emerging as a global leader in developing the technology, with government backing. The UK has the ocean energy resources, a long relationship with the sea and outstanding inventive talent. The first country to commercialise this British invention on a significant scale is Portugal. After sea trials starting in 2004, the first major commercial installation of the Pelamis Wave Energy Converter took place in Portuguese waters, and wave energy came to life. First tested in 2000, in 2004 Wavegen, an OWC (oscillating water column), is being tested to provide power to the Faroe Islands. In 2003 Wave Dragon, a floating Tapchan, demonstrated its survivability off Norway. On the other side of the world, Korea is embarking on a series of tidal barrages, starting with the 254 Mw Shiwah Barrage which will be the largest in the world, due for commissioning in 2009 overtaking La Rance in France.

So far four technologies have been at the forefront of experimentation, Tidal Barrages, Wave Energy, Tidal or Marine Current Power, and OTEC, but a fifth has been know about for some years, although it has largely been ignored and few people have heard of it. This is the Salinity Gradient, which exploits the osmotic pressure difference between fresh water and sea water. It has the largest potential energy capacity of any of the ocean energy conversion technologies and is now attracting attention. Learn about it in this Report.

Ocean energy is mostly in an experimental stage but some of its component technologies have the potential to become mainstream energy sources and are now being trialled. Many ideas have been generated and a lot of experimental projects are being funded both by governments and commercially. Until recently it was commonly said that energy can be harvested from the oceans in four ways, but now it is five:

- Tidal Energy
- Wave Energy
- Ocean Thermal Energy Conversion (OTEC)
- Marine Current Energy, and
- Salinity Gradient

Report Scope

The report outlines these technologies, with their state of development as technologies and industries. The report focuses on a small number of exciting new developments. The status of each industry is described in each country where it has a base or is under trial, and the state of commercialisation. A key fact now emerging is the need to transfer technology and know-how from the offshore industry to the new marine renewable energy industry. The offshore oil and gas industry has already contributed substantially to the development of offshore wind power technology (See ABS Wind Report). No country is better equipped to exploit this than the UK. It is also becoming clear to many companies in the offshore oil & gas industry that with resource depletion, their future lies in a capability to diversify their skills and services into other business sectors, one being off-shore renewable energy sources. This synchronicity is a key driver to the development of ocean energy conversion.

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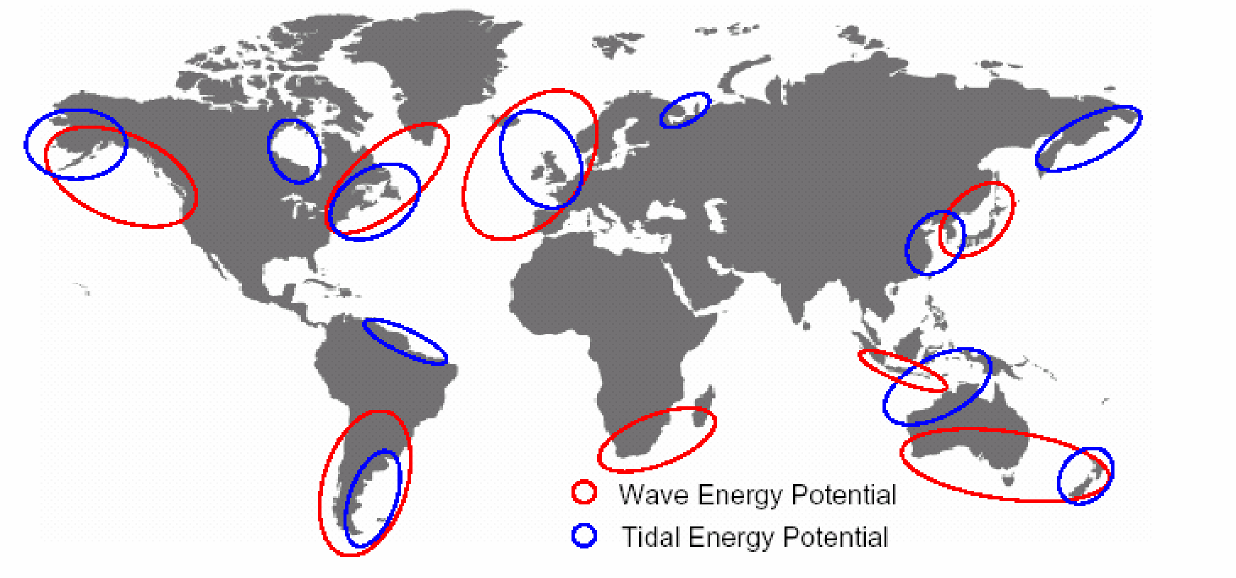
2. Tidal Energy

Tidal power functions similarly to a hydroelectric scheme but with a larger dam. A “barrage,” a giant dam, is built across a river estuary. Water flows through tunnels in the dam as the tides change. The ebb and flow of the tides can be utilised in two ways: to turn a turbine or to push air through a pipe, which then turns a turbine. Ships are able to pass through lock gates, like the ones used on canals.

Tidal ranges vary greatly from place to place because of the effects of local geography, such as the seabed and headland, which can cause funnelling, reflections, and resonance effects. The average range around the world is about 1 metre, but some locations experience tidal ranges which are much greater. The most suitable are generally between 5 and 10 metres. The other requirement, a large storage basin, is normally satisfied by choosing a wide river estuary or natural bay.

Figure 2.1: The Global Tidal Resource



Source: Scottish Enterprise

Tides are caused by the gravitational pulls of the moon and sun acting upon the oceans of the rotating earth. The relative motions of these bodies cause the surface of the oceans to rise and fall periodically according to a number of interacting cycles.

- A half day cycle, due to the rotation of the earth within the gravitational field of the moon.
- A 14 day cycle, resulting from the gravitational field of the moon combining with that of the sun to give alternating spring (maximum) and neap (minimum) tides.
- A half year cycle, due to the inclination of the moon's orbit to that of the earth, giving rise to maxima in the spring tides in March and September.
- Other cycles, such as those over 19 years and 1,600 years, arising from further complex gravitational interactions.

The range of a spring tide is commonly about twice that of a neap tide, whereas the longer period cycles impose smaller perturbations. In the open ocean, the maximum amplitude of the tides is about one metre. Tidal amplitudes are increased substantially toward the coast, particularly in estuaries. This is mainly caused by shelving of the seabed and funnelling of the water by estuaries. In some cases, the tidal range can be further amplified by reflection of the tidal wave by the coastline or resonance. This is a special effect that occurs in long, trumpet-shaped estuaries when the length of the estuary is close to one quarter of the tidal wave length. These effects combine to give a mean spring tidal range of over 11 metres in the Severn Estuary (UK). As a result of these various factors, the tidal range can vary substantially between different points on a coastline. The amount of energy obtainable from a tidal energy scheme therefore varies with location and time. Output changes as the tide ebbs and flows each day; it can also vary by a factor of about four over a spring-neap cycle.

The available energy is approximately proportional to the square of the tidal range. Extraction of energy from the tides is considered to be practical only at those sites where the energy is concentrated in the

3. Wave Energy

Wave energy the largest of the ocean energy resources.

Contrary to 'flow' energy converters that extract energy from ocean currents, 'wave' energy conversion devices convert energy contained in ocean waves into electric energy. Wave energy is generated by the movement of either stationary or floating devices on the surface of the ocean, moved by waves, rather than by a large volume of tidal water such as is used to drive motors. These devices are called wave energy Converters (WECs).

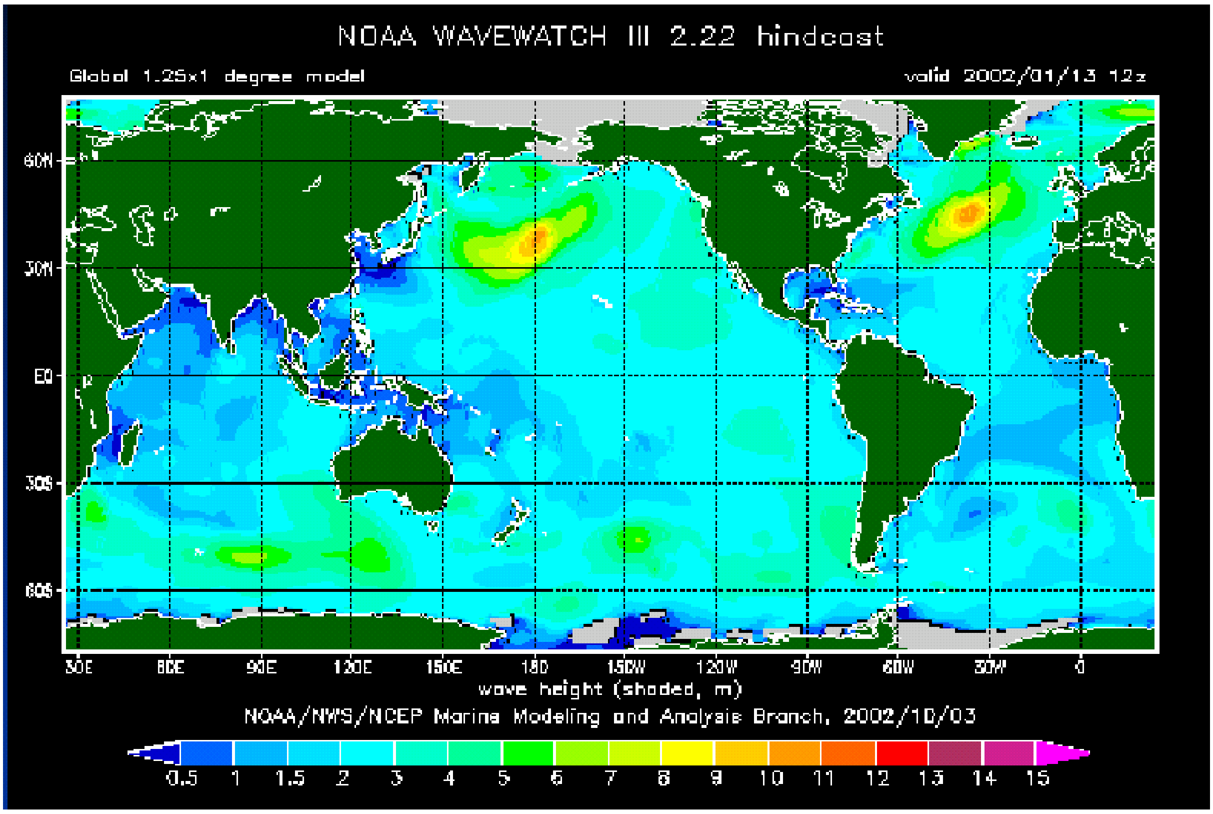
Ocean mechanical energy is quite different from ocean thermal energy. Even though the sun affects all ocean activity, tides are driven primarily by the gravitational pull of the moon, and waves are driven primarily by the winds. As a result, tides and waves are intermittent sources of energy, while ocean thermal energy is fairly constant. Also, unlike thermal energy, the electricity conversion of both tidal and wave energy usually involves mechanical devices.

At the generic level, a recent review of wave energy R&D requirements by Ove Arup concluded that there were no fundamental technical barriers to the development of this technology. The review noted that many issues relating to design, construction, deployment and operation could be addressed by technology from other industries, notably the offshore industry. However, it did identify some technology gaps, notably in the areas of mooring, cable connections, hydraulic machines, grid connection and energy storage.

Wave resources

The highest energy waves are concentrated off the western coasts in the 40°–60° latitude range, north and south. The power in the wave fronts varies in these areas between 30 and 70 kW/m, with peaks to 100kW/m in the Atlantic Southwest of Ireland, the Southern Ocean, and off Cape Horn. The capability to supply electricity from this resource is such that, if harnessed appropriately, 10% of the current level of world supply could be provided. Work is still needed to determine how much more may be captured by other products, such as pumped water for desalination or electrolysis, once the storage technology for hydrogen is suitably developed.

Figure 3.1: Wave power resources of the world



Source: US National Oceanic and Atmospheric Administration

9. Benefits of Different Forms of Energy

The following table summarises the benefits and disadvantages of the different forms of conventional and renewable energy. With the exception of capital cost, ocean energy has many advantages, and the capital cost will be reduced with development.

Table 9.1: The Advantages and Disadvantages of Different Energy Technologies

	Renewable resource	Low capital cost	Low running cost	Minimal environmental impact	Predictable	Intermittency	Minimal Visual impact	Modular	Base load
Fossil	✗	✓	✗	✗	✓	✗	✗	✗	✓
Nuclear	✗	✓	✗	✗	✓	✗	✗	✗	✓
Wind	✓	✗	✓	✓	✗	✓	✗	✓	✗
Solar	✓	✗	✓	✓	✗	✓	✗	✓	✗
Hydro	✓	✓	✓	✗	✓	✗	✗	✗	✓
Tidal	✓	✗	✓	✗	✓	✓	✗	✗	✗
Wave	✓	✗	✓	✓	✓	✓	✓	✓	✓
Ocean Thermal	✓	✗	✓	✓	✓	✗	✓	✓	✓
Marine Current	✓	✗	✓	✓	✓	✓	✓	✓	✓

Source: World Energy Council and ABS Energy Research

Note: in their present stages of technological and industrial development, the capital and running costs of the four ocean energy forms are not yet fully down to the competitive levels they will reach. Wind and solar power both achieved progress ratios of 0.8 in their early years of development and ocean energy can do the same. (The progress ratio is a measurement used in industrial learning curve theory to evaluate the progress of a new technology's development. It means that for each doubling in volume manufactured the unit cost in the second half falls to 80% of the first half.

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