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Harnessing Energy from the Oceans

Forever moving - our restless oceans have enough energy to power the world. As long as the Earth turns and the moon keeps its appointed cycle, the oceans will absorb and dissipate vast amounts of kinetic energy - a renewable energy resource of enormous potential. But harnessing this resource has proven more difficult than first thought. In this the latest installment of the GLOBE-Net Series on Renewable Energy - we look at how the power of the oceans might eventually find its place among other forms of renewable energy.

Ocean Energy - What is it?

According to the United Nations, 44% of the world's population lives within 150 km of an ocean coast. In Canada and Australia the number is much higher at 80%. In the United States 53% of the population lives in close proximity to an ocean.

Thus it is only natural that many countries look to the oceans as a source of energy to be harnessed. How they seek to exploit this resource varies according to factors of geography and available technologies.

The two main forms of energy associated with our oceans are tidal power and wave power - born of the same source, but different in how they turn energy into electricity.

Tidal Power

Tidal power coverts the energy of tides into electricity utilizing the rise and fall of the ocean tides. The stronger the tide, either in water level height or tidal current velocities, the greater the potential for tidal electricity generation.

Tidal generators act in much the same way as do wind turbines, however the higher density of water (832 times that of air) means that a single generator can provide significant power at velocities much lower than those associated`with the wind power generators.

Tidal power can be classified into two main types; Tidal Stream Systems and Barrages.

Barrages are similar to hydro-electric dams but are placed in an estuary bay or river mouth, where they act as barriers that create artificial tidal lagoons. When water levels outside the lagoon changes relative to water levels inside, turbines in the barrages are able to produce electrical power. There are only three such structures in the world: the Rance River in France, Canada's Bay of Fundy, and Kislaya Guba, Russia.

Tidal stream systems make use of the kinetic energy of moving water to power turbines. This technology simply relies on individual turbines which are placed in the water column; moored to be suspended, floating or anchored to the ocean floor. As the tide flows in or out, electrical energy is produced as water moves through the turbine.

Tidal power boasts several advantages over other types of renewable energy technology, because tides are more predictable and reliable than wind energy or sunny days for solar power. Tidal energy has an efficiency ratio of approximately 80% in terms of converting the potential energy of the water into electricity. Tidal stream system turbines are only a third the diameter of wind rotors of the same power output.

As with wind power, location is important factor in terms of being able to harness the earth's natural energy. Tidal stream systems must be located in areas with fast currents where natural flows are concentrated between natural obstructions, for example at the entrances to bays and rivers, around rocky points or headlands, or between islands and other land masses.

Wave Power

Ocean surface waves are also a considerable source of energy potential, but energy that is not as restricted in terms of location as tidal energy systems. Typically wave energy is captured using buoys which generate mechanical energy as they oscillate vertically from wave motion.

Terminator devices extend perpendicular to the direction of wave travel and capture or reflect the power of the wave. Water enters through a subsurface opening into a chamber with air trapped above it and wave action causes the captured water column to move up and down like a piston to force the air though an opening connected to a turbine.

A point absorber is a floating structure with components that move relative to each other due to wave action (e.g., a floating buoy inside a fixed cylinder). The relative motion is used to drive electromechanical or hydraulic energy converters.

Attenuators are long multi-segment floating structures oriented parallel to the direction of the waves. The differing heights of waves along the length of the device causes flexing where the segments connect, and this flexing is connected to hydraulic pumps or other converters.

Overtopping devices have reservoirs that are filled by incoming waves to levels above the average surrounding ocean. The water is then released, and gravity causes it to fall back toward the ocean surface. The energy of the falling water is used to turn hydro turbines.

Wave power varies considerably in different parts of the world, and wave energy can't be harnessed effectively everywhere. According to the Ocean Renewable Energy Group, a Vancouver based organisation that promotes the development of ocean energy in Canada, regions considered to have "good" wave energy resources are generally those found within 40 to 60 degrees of latitude, where the strongest winds are found. Wave-power rich areas of the world include the western coasts of Scotland, northern Canada, southern Africa, Australia, and the northwestern coasts of the United States.

Projects Underway

Ocean energy company Clean Current Power Systems estimates a potential global market for 67,000 Megawatts (MW) of tidal and wave action equipment worth $200 billion. At 20 cents/kW hour, the market for tidal electricity could be $27 billion annually. According to Finavera, world-wide wave energy could provide up to 2,000 TWh/year, 10% of world electricity consumption.

It comes as no surprise then, that interest in ocean energy has been building momentum in the past few years as these nations scramble to meet renewable energy targets.

For instance, in November 2007, British company Lunar Energy announced that it would be building the world's first deep-sea tidal-energy farm off the coast of Pembrokshire in Wales. Eight underwater turbines, each 25 metres long and 15 metres high will provide electricity for 5,000 homes. Construction is due to start in the summer of 2008 and the proposed tidal energy turbines, described as "a wind farm under the sea", should be operational by 2010.

Plans for a ten-mile barrage across the River Severn, which could generate 5% of the UK's electricity needs, are currently under development. According to the UK Sustainable Development Commission, a barrage across the Severn would produce clean and sustainable electricity for 120 years. This would have a capacity of 8,640MW and an estimated output of 17 terawatt hours a year.

Scotland boasts roughly 25% of the entire European Union's tidal power potential and 10% of its wave energy potential and could produce more than 1,300 megawatts by 2020, enough to power a city the size of Seattle. In 2007, Scotland announced $26 million worth of funding packages to develop marine power in the nation. So far $8 million has been procured to develop 3 MW of tidal power.

UK based Marine Current Turbines is developing a tidal stream system off the coast of Ireland. The 1.2-megawatt turbine will be tested for 12 weeks before feeding power into the Northern Ireland grid where it will operate for up to 20 hours per day, producing enough electricity to power 1,000 homes.

Both Scotland and England are planning wave energy projects. Scotland will be developing a 3MW array and England will be developing a 20 MW Wave Hub off the north coast of Cornwall, England. The Cornwall project will power up to 7,500 homes.

Canada has the world's longest coastline and has always been serious about harnessing ocean energy. In early 2008 the Government of Nova Scotia gave the green light to three tidal energy testing projects in the Bay of Fundy to help establish a permanent tidal energy farm (see GLOBE-Net Article Nova Scotia to fund tidal power research). Irving Oil is also studying 11 potential sites in the Bay of Fundy to develop tidal energy farms.

The Government of British Columbia estimates there are more than 6,000 megawatts of potential wave energy that have been identified so far in the province and projects are already underway to develop wave energy systems. In 2006 Vancouver based Clean Current Power Systems began developing a pilot tidal power project near Victoria to demonstrate the potential for tidal power.

Pacific Gas and Electric Company and Vancouver-based Finavera Renewables is developing America's first commercial wave power plant off the coast of Northern California. The plant is scheduled to begin operating in 2012, generating a maximum of 2 megawatts of electricity.

In March, 2008, the U.S. Department of Energy announced would be offering up to $7.5 million in grants for hydro-kinetic energy such as wave and tidal power. The department is seeking partnerships with companies and universities to develop the technologies and plans to award up to 17 grants.

Portugal is planning the world's first commercial wave farm, the AguÃ§adora Wave Park near PÃ³voa de Varzim. If successful, a further 70 million euro is likely to be invested before 2009 on a further 28 machines to generate 72.5 MW.

The Challenges

Despite the enormous potential of ocean energy, there remain many pitfalls (if such a word can be used in a watery context) that have proven difficult to overcome, and which explains why ocean energy remains the least developed of all forms renewable energy. Problems still exist regarding cost, maintenance, environmental concerns and our still imperfect understanding of how power from the oceans will impact on the world's energy infrastructure.

For example, turbines are susceptible to bio-fouling; the growth of aquatic life on or in the turbine. This can severely inhibit the efficiency of energy production and is both costly and difficult to remove. Turbines are also prone to damage from ocean debris.

In the Bay of Fundy, project developers are particularly concerned with ice floes the size of small apartments, and cobblestones the size of watermelons constantly being tossed across the Bay's terrain by the power of the Bay's water flows.

Turbines may also be hazardous to marine life and the impacts on marine life are still largely unknown, but concern is warranted.

Barrage systems are affected by problems of high initial infrastructure costs associated with construction and the resulting environmental problems. For example, independent research on the economics of building the proposed Severn Barrage in the UK revealed that, taking environmental costs into account, the structure could cost as much as $12 billion to create - $4 billion more than previously estimated.

Barrage impacts include a decrease in the average salinity and turbidity within a barrage, significantly altering associated ecosystems.

Wave power systems present their own set of challenges. Most electric generators operate at higher speeds, and most turbines require a constant, steady flow. Unfortunately wave energy is slow and ocean waves oscillate at varying frequencies.

The rough realities of the marine environment have also proven difficult to deal with, especially for companies seeking to remain cost-effective. Constructing wave devices that can survive storm damage and saltwater corrosion add to development costs.

The Future

Modern advances in ocean energy technology may eventually see large amounts of power generated from the ocean, especially tidal currents using the tidal stream designs. The technology is still in its infant stage and most projects that exist or are that are in project development stages are mainly pilot projects. But the promise remains.

"It's not as well-established as solar, thermal, wind and biomass, but it [ocean power] shows a lot of promise," said Philip Jennings, professor of energy studies at Western Australia's Murdoch University.

"As the technology develops and becomes more affordable, which it will over time, we can continue to expand pretty much anywhere where there is an ocean," said Chief Executive Officer Phil Metcalf of Pelamis Wave Power.

The market potential for tidal power still remains unclear [says who?]. Sector analysts believe Initial Public Offerings (IPO) for wave and tidal power projects will be much harder to price than for comparable wind power projects, because wave firms cannot give exact estimates on the scale of benefits and few have technologies that are up and running.

Regardless, both ocean wave and tidal power have attracted growing interest from investors and power utilities looking for the next long-term play in renewable energy.

"Water covers more than 70 percent of the Earth's surface," said Andy Karsner, assistant secretary for energy efficiency and renewable energy at the DOE. "Using environmentally responsible technologies, we have a tremendous opportunity to harness energy produced from ocean waves, tides or ocean currents, free-flowing water in rivers and other water resources to...provide clean and reliable power."

According to Jennings ocean power could not match fossil fuels for electricity production but could be competitive with other forms of renewable energy.