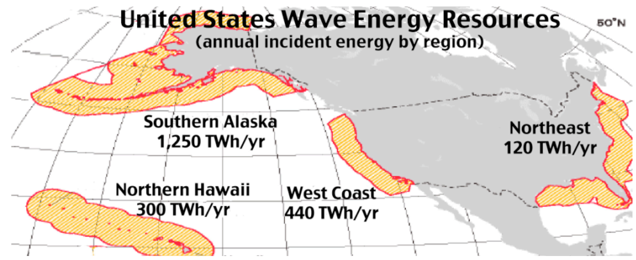
Wave and Tidal

Renewable Northwest Project



WAVE AND TIDAL ENERGY IN THE NORTHWEST		
Total Annual U.S. Incident Wave Energy		2,110 terawatt-hours
Technology:	Wave Energy	Tidal Energy
Current Levelized Cost (2006$)	~10-30 cents/kWh	~8-12 cents/kWh
Future Levelized Cost (2006$)	~5-6 cents/kWh	~4-6 cents/kWh
Resource Type	Variable, predictable	Variable, highly predictable

kWh = kilowatt-hours. 1 terawatt-hour = 1 billion kWh.
Sources: see endnote 1.

What Is Wave and Tidal Energy?

In addition to its abundant solar, wind and geothermal resources, the Pacific Northwest is also uniquely situated to capture the renewable energy of the ocean. Special buoys, turbines, and other technologies can capture the power of waves and tides and convert it into clean, pollution-free electricity. Like other renewable resources, both wave and tidal energy are variable in nature. Waves are produced by winds blowing across the surface of the ocean. However, because waves travel across the ocean, their arrival time at the wave power facility may be more predictable than wind. In contrast, tidal energy, which is driven by the gravitational pull of the moon and sun, is predictable centuries in advance.

The technologies needed to generate electricity from wave and tidal energy are at a nascent stage, but the first commercial projects are currently under development, including some in the Pacific Northwest. Like most emerging energy technologies, wave and tidal technologies are currently more expensive than traditional generating resources, but with further experience in the field, adequate R&D funding, and proactive public policy support, the costs of wave and tidal technologies are expected to follow the same rapid decrease in price that wind energy has experienced.

Potential

Worldwide potential for wave and tidal power is enormous, however, local geography greatly influences the electricity generation potential of each technology. Wave energy resources are best between 30º and 60º latitude in both hemispheres, and the potential tends to be the greatest on western coasts.

The United States receives 2,100 terawatt-hours of incident wave energy along its coastlines each year, and tapping just one quarter of this potential could produce as much energy as the entire U.S. hydropower system. Oregon and Washington have the strongest wave energy resource in the lower 48 states and could eventually generate several thousand megawatts of electricity using wave resources.[2] Several sites in Washington's Puget Sound with excellent tidal resources could be developed, potentially yielding several hundred megawatts of tidal power.[3]

While no commercial wave or tidal projects have yet been developed in the United States, several projects are planned for the near future, including projects in the Northwest. AquaEnergy Group, Ltd is currently designing and permitting a one-megawatt demonstration wave power plant at Makah Bay, Washington. Ocean Power Technologies has received a preliminary permit to explore construction of North America's first utility-scale wave energy facility off the coast of Reedsport, Oregon. With the support of the Oregon Department of Energy, Oregon State University is also seeking funding to build a national wave energy research facility near Newport, Oregon. Several tidal power projects are also being explored in the region. Tacoma Power has secured a preliminary permit to explore a tidal power project at the Tacoma Narrows, one of the best locations for tidal power in the country, and Snohomish County Public Utility District has received preliminary permits for seven other potential tidal power sites in the Puget Sound.[4]

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Wave Energy Technologies

There are three main types of wave energy technologies. One type uses **floats, buoys, or pitching devices** to generate electricity using the rise and fall of ocean swells to drive hydraulic pumps. A second type uses **oscillating water column (OWC) devices** to generate electricity at the shore using the rise and fall of water within a cylindrical shaft. The rising water drives air out of the top of the shaft, powering an air-driven turbine. Third, a **tapered channel, or overtopping device** can be located either on or offshore. They concentrate waves and drive them into an elevated reservoir, where power is then generated using hydropower turbines as the water is released. The vast majority of recently proposed wave energy projects would use offshore floats, buoys or pitching devices.

The world's first commercial offshore wave energy facility will begin operating by the end of 2007 off the Atlantic coast of Portugal. The first phase of the project, which Scottish company, Ocean Power Delivery (OPD) developed, features three 'Pelamis' wave energy conversion devices and generates a combined 2.25 MW of electricity. OPD plans to expand the facility to produce 22.5 MW in 2007.[5]

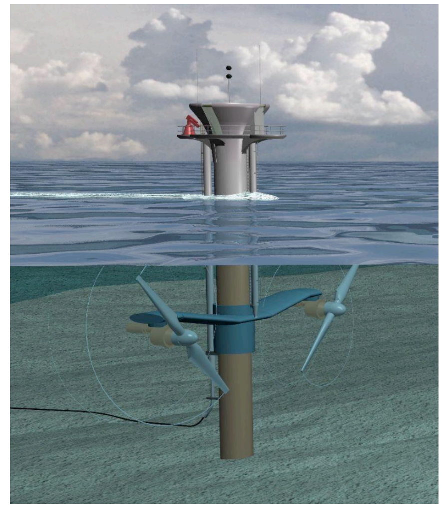
Tidal Power Technologies

Until recently, the common model for tidal power facilities involved erecting a **tidal dam, or barrage,** with a sluice across a narrow bay or estuary. As the tide flows in or out, creating uneven water levels on either side of the barrage, the sluice is opened and water flows through low-head hydro turbines to generate electricity. For a tidal barrage to be feasible, the difference between high and low tides must be at least 16 feet. La Rance Station in France, the world's first and still largest tidal barrage, has a rated capacity of 260 MW and has operated since 1966. However, tidal barrages, have several environmental drawbacks, including changes to marine and shoreline ecosystems, most notably fish populations.[6]

Several other models for tidal facilities have emerged in recent years, including **tidal lagoons, tidal fences, and underwater tidal turbines,** but none are commercially operating. Perhaps the most promising is the **underwater tidal turbine**. Several tidal power companies have developed tidal turbines, which are similar in many ways to wind turbines. These turbines would be placed offshore or in estuaries in strong tidal currents where the tidal flow spins the turbines, which then generate electricity. Tidal turbines would be deployed in underwater 'farms' in waters 60-120 feet deep with currents exceeding 5-6 mph. Because water is much denser than air, tidal turbines are smaller than wind turbines and can produce more electricity in a given area.[7] A pilot-scale tidal turbine facility – the first in North America – was installed in New York's East River in December 2006. The developer, Verdant Power, hopes to eventually install a 10 MW tidal farm at the site.[8]

Environmental Impacts

Unlike fossil-fueled power plants, wave and tidal energy facilities generate electricity without producing any pollutant emissions or greenhouse gases. Since the first wave and tidal energy facilities are currently being deployed, the full environmental impacts of wave and tidal power remain uncertain but are projected to be small. Concerns include impacts on marine ecosystems and fisheries. Environmental impact studies are currently underway and several pilot and commercial projects are undergoing environmental monitoring. The East River tidal turbine pilot project includes a $1.5 million sonar system to monitor impacts on fish populations, for example.[9] Careful siting should minimize impacts on marine ecosystems, fishing and other coastal economic activities. Wave and tidal facilities also have little or no visual impact, as they are either submerged or do not rise very far above the waterline.



Graphic: Artist's representation of an underwater tidal turbine. (Source and copyright: Marine Current Turbines, Ltd.)

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[1] Wave energy resource figure and graphic from: *Project Definition Study: Offshore Wave Power Feasibility Demonstration Project,* Electric Power Research Institute (EPRI), (Jan 2005), p 12.

-Wave energy levelized costs from correspondence with Des McGinnes of Ocean Power Delivery (Nov 2006).

-Tidal energy levelized costs from *North American Tidal In-Stream Energy Conversion Technology Feasibility Study,* EPRI (June 2006), pgs 5-6.

[2] EPRI *op. cit.* note 1, p 28.

[3] "Tides hold promise of electricity." *The Daily Herald* (Everett, WA), 2/11/07. http://www.heraldnet.com/stories/07/02/11/100loc_a1sunpower001.cfm.

[4] "Current Projects", AquaEnergy Group, Ltd. (2006), http://aquaenergygroup.com/projects/index.php, accessed 10/18/06.

-"Agreement to Develop Wave Park in Oregon", *RenewableEnergyAccess.com*, 2/23/07, http://www.renewableenergyaccess.com/rea/news/story?id=47546&src=rss, accessed 4/2/07.

- *The Daily Herald*, *op. cite.* note 3.

[5] "Energy Portugal: Riding the Wave of the Future", *InterPress News Agency,* 9/27/06, http://ipsnews.net/news.asp?idnews=34898, accessed 10/19/06.

[6] *Renewable Energy Fact Sheet,* Environmental and Energy Study Institute, (May 2006).

[7] Depth and current speed requirements from "Background", Marine Current Turbines (MCT), (2002), http://www.marineturbines.com/background.htm, accessed 10/17/06.

[8] *The Daily Herald*, *op. cite.* note 3.

[9] "Energy From the Restless Sea", *New York Times*, 7/3/06.