

# Oceanic Engineering and Offshore Energy Production

William M. Carey  
Energy Committee Co-chair  
Boston University  
Boston, MA 02215  
(wcarey@bu.edu)

Claude P Brancart  
Energy Committee Co-chair  
Brunswick, ME 04011  
(c.brancart@ieee.org)

The Annual Energy Outlook 2008 <sup>[1]</sup> prepared by Energy Information Administration of the United States Department of Energy projects the continued use of fossil fuels (liquids, coal and natural gas) with little emphasis on “Oceanic Energy Conversion” and marginal importance to “Off-shore Wind Energy conversion.” However the potential energy available for conversion to electrical energy along the coastal United States and the Ocean in general is considerable. Von Jouanne <sup>[2]</sup> estimated that “2 one-thousandths of the oceans’ untapped energy could provide power equal to current worldwide demand.” This paper provides an overview of oceanic energy production technologies highlighting surface wave motion, tidal height variations and subsurface currents, oceanic currents, ocean thermal-gradient energy conversion, and wind generation technologies.

Current offshore wave power systems employ both horizontal pontoon and vertical buoy turbines. Wave motion forces the segments of the pontoon to move relative to each other, actuating hydraulic rams, which force oil through small turbine generators producing ~750 kw. Wave motion oscillates a piston inside the vertical buoy system that drives a fluid through a turbine generator producing ~ 150 kw.

Tide ponds and barrages are the most basic and conventional method for collecting tidal energy. Water is captured during high tide and flows out during low tide. Motion of the rising and falling water drives the turbines to create electricity (e.g. collect energy from tidal potential) The tidal barrage is similar to a dam across a bay or an estuary and generates power from ebb tides with heads greater than five meters. One of the barrage largest systems, the French La Rance Tidal Barrage completed in 1967 by Charles de Gaulle, is a facility with (24)-10MW turbines and uses two-way flow to generate to 240 MW of electrical power.

Tidal fences are a combination a barrage and offshore turbines without many of the environmental effects can encloses an area by linking single units together; power is produced by energy from free flowing stream. When applied across Straits tidal fences can provide considerable electrical energy. These systems deployed in tidal archipelagos or in straits can be configured as megawatt power plants. In fact a planned 2.2 GW plant with 274 turbines aligned in tidal fences is under a phased construction in the San Bernardino Strait, the Philippines.

Large off-shore that produce electrical energy from subsurface vertical and horizontal turbines take advantage of currents between 2-2.5 m/s and can produce approximately four times the energy of off-shore wind. These systems are attractive since ocean currents are fairly predictable and periodic. Large-scale farms are found in coastal Europe with energy production of 300-750 kw/turbine and 10 MW/ km<sup>2</sup>. The proximity to shore and the almost periodic nature of the production provides a means of connecting to a power grid as reliable energy sources. Subsurface turbines farms in areas of large steady currents are also attractive but are usually further from shore and thus increased energy storage and transmission requirements are realized.

J. D’Arsonval (1881) proposed, ocean thermal energy conversion, Otec, based on the utilization of an ammonia cycle and the ocean temperature differential. In 1982 a land based plant in Nauru developed and delivered power (16 kW for 12 months ) to the electrical grid. The “Uehara” Cycle with a higher efficiency of 5-6% was later developed in 1994. Concurrently, the Hawaiian Otec Experimental Plant (1993-1998) produced 103 kW of power and was largest and most efficient land unit to date. A larger,

Hawaiian-land-based, closed-cycle Otec plant could produce electricity with a second-stage desalinated water production system. This type of system (50 MW or larger) is cost effective because diesel fuel costs have doubled. Recently Sea Solar (2002) has designed a floating 100 MW Otec ship. Cold water is drawn up a 3300 foot long 28 foot diameter (1000m x 8.5m) stockade pipe. A spring collar decouples the near neutrally buoyant cold water pipe from ship motion. The 5,000 cubic foot per second (142 m<sup>3</sup>/s) cold-water flow is directed through multiple pass condensers and propylene vapor turbines power the four cold-water pumps. Propylene vapor from the boilers travels upwards through twelve turbines, and is then condensed into liquid in the cold-water condensers. Due to the elevation of the condensers above the boilers, there is sufficient pressure head in the condensate lines to force the liquid propylene back into the boilers without the need for feed pumps. Power is converted to high voltage DC, and is cabled to the local shore based power grid.

Wind is an intriguing option since it constitutes 2 % of the available global energy. There are two major issues for oceanic wind. The first is the environmental permitting process and concerns over animal habitats and bird safety and the second is the current technology cost. The United States has capability of 16,800 MW with 3,600 MW planned. Denmark currently has enough wind power to cover 19 percent of the electricity demand while Spain and Germany have approximately 5 to 8 percent. Europe, generates over 56,000 MW of electrical power. Offshore wind is a resource that been under utilized mainly because of the complications in construction, permitting, transmission and maintenance however it can produce energy during portions of the year that require heating and air conditioning. One such area is the New England Coast that has characteristically high average wind speeds. Similar technology can be used in the Great Lakes regions. The off shore wind farm is an Oceanic Engineering challenge due to the construction, maintenance and transmission requirements. Wind energy is also available far from shore but has prohibitive electrical transmission problems, thus the question of energy storage becomes an important technology.

Many oceanic engineering research and technology issues of interest are common to all of these conversion schemes ranging from new and improved moorings, site surveys, construction of pilings, cable and hub laying technologies, automated subsurface inspections, surveillance, maintenance and a host of materials and turbine technology issues. While the potential for energy production exists its utilization will require extensive development.

#### REFERENCES

- [1] Annual Energy Outlook 2008 (AEO2008), Report #:DOE/EIA-0383(2008), June 2008, National Energy Information Center, EI-30 Energy Information Administration, Forrestal Building Washington, DC 20585
- [2] Von Jouanne, Annette. "Harvest the Waves." Mechanical Engineering. 128 (2006): 24-27.