

Sustainable Energy

Lecture 14: Ocean Waves

Energy from the Tides

- Tides arise from gravitational interactions (earth/moon 68%; sun 32%).
- Most tides occur twice a day; a high tide and low tide.
- Some locations on earth are more favorable than others for tidal flux.

Ocean Energy

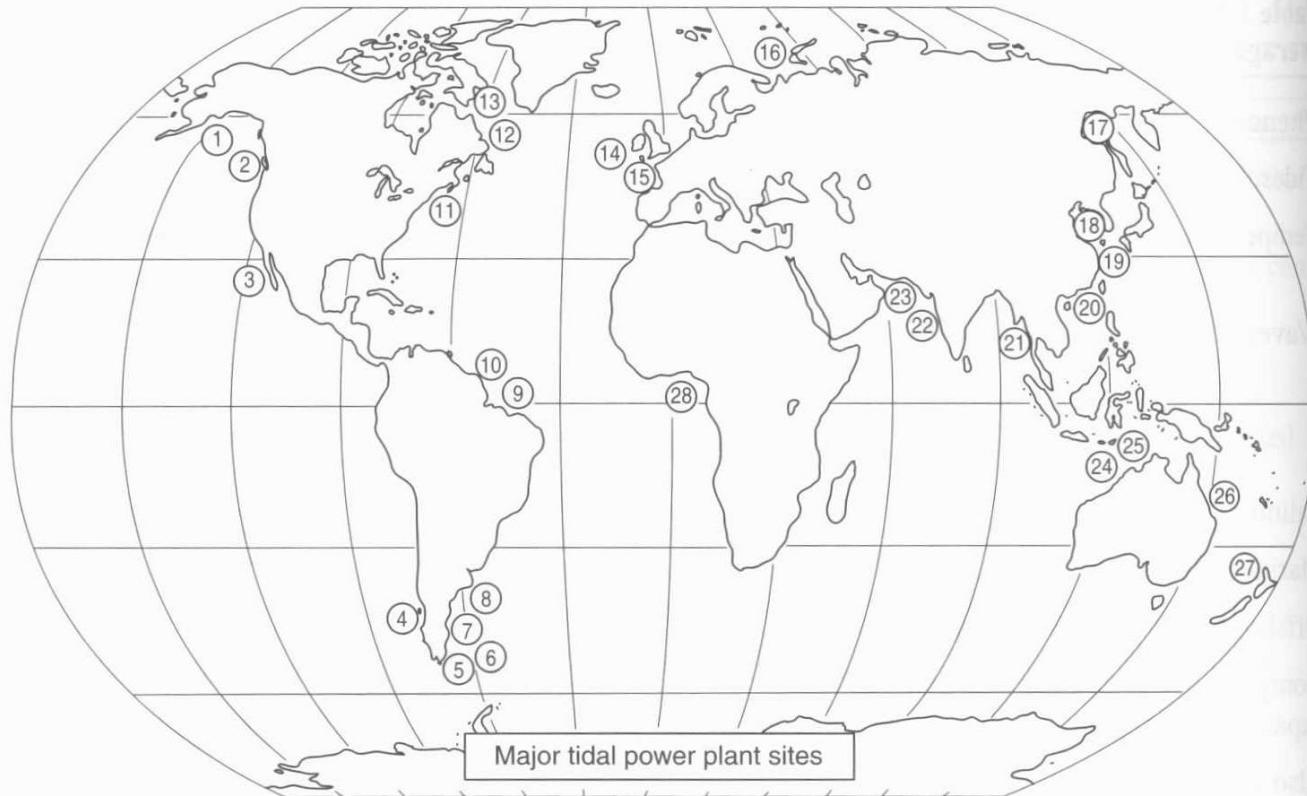
Table 14.3. Approximate Worldwide Ocean Energy Available (all values are Gigawatts, annual average)

Phenomenon	Maximum Potential	Practicable to Exploit
Tides	2,500 (total dissipation)	20
Temperature Difference (OTEC)	2×10^5 (based on total absorbed insolation in equatorial waters)	near or onshore: 40 offshore: 10,000
Waves	2,700 (on all the world's coastlines) 10,000 (open sea renewal rate)	500
Salinity Gradients	10^6	not presently viable
Marine Currents	5,000	50
Offshore near-surface winds	20,000	1,000
Compare world electric energy installed capacity.		in 1998: 2,800, of which US is: 750
Also compare world freshwater hydroelectric currently installed capacity at 550 GWe and total potential capacity of about 4,000 GWe.		

Energy from the Tides/Waves

- Different types of wave technologies:
 - Barrage (La Rance; France; 240 MW)
 - Float driven devices
 - Tidal stream generators
- The higher density of water, 832 times the density of air, means that a single generator can provide significant power at low tidal flow velocities (compared with wind speed). Given that power varies with the density of medium and the cube of velocity, it is simple to see that water speeds of nearly one-tenth of the speed of wind provide the same power for the same size of turbine system.

Tidal Power Plant Sites



1. Cook Inlet;
2. British Columbia;
3. Baja California;
4. Chonos Archipelago;
5. Magellan Straits;
6. Gallegos/Santa Cruz;
7. Gulf of San Jorge;
8. San Jose Gulf;
9. Maranhão;
10. Araguaia;
11. Fundy/Quoddy;
12. Ungava Bay;
13. Frobisher Bay;
14. Severn/Solway;
15. Rance;
16. Mezen/Kislaya;
17. Okhotsk Sea;
18. Seoul River;
19. Shanghai;
20. Amoy;
21. Rangoon;
22. Cambay Bay;
23. Rann of Kutch;
24. Kimberleys;
25. Darwin;
26. Broad Sound;
27. Manukau;
28. Abidjan.

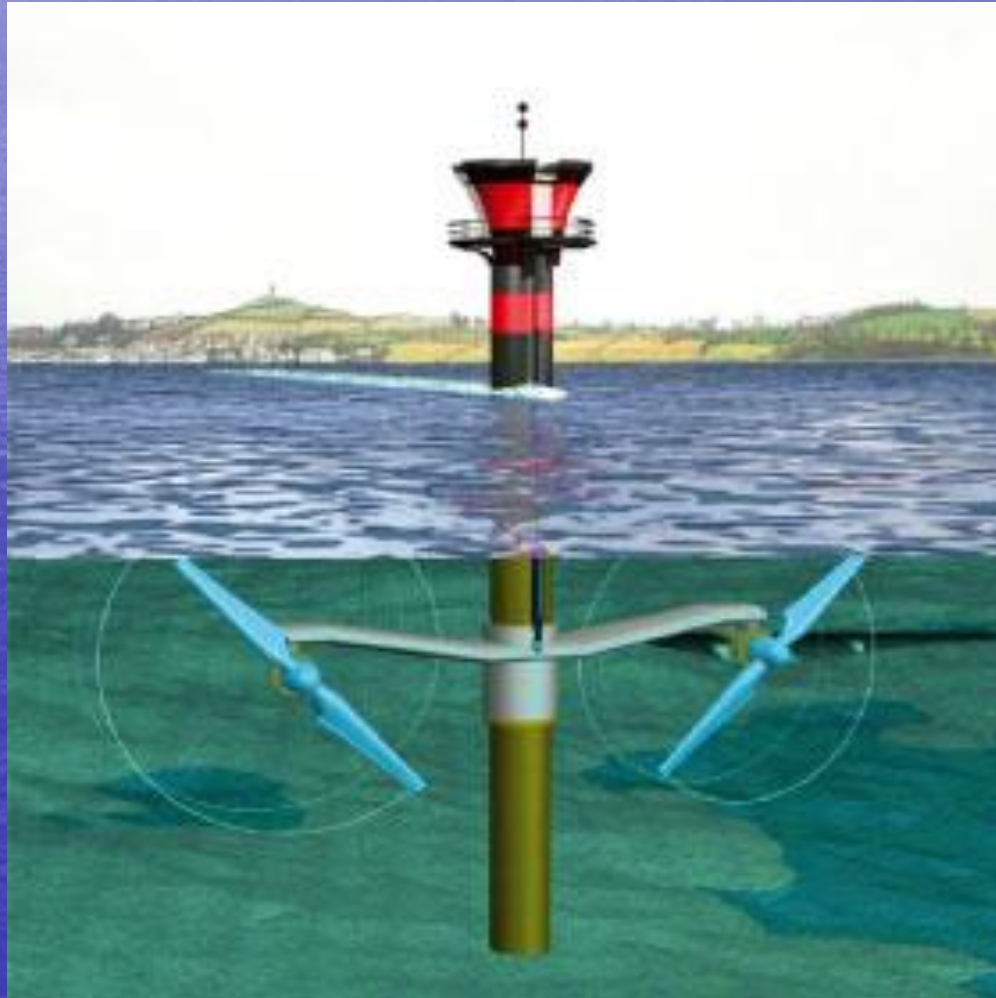
Barrage/Rance



Sea Gen /Devon England



Sea Gen

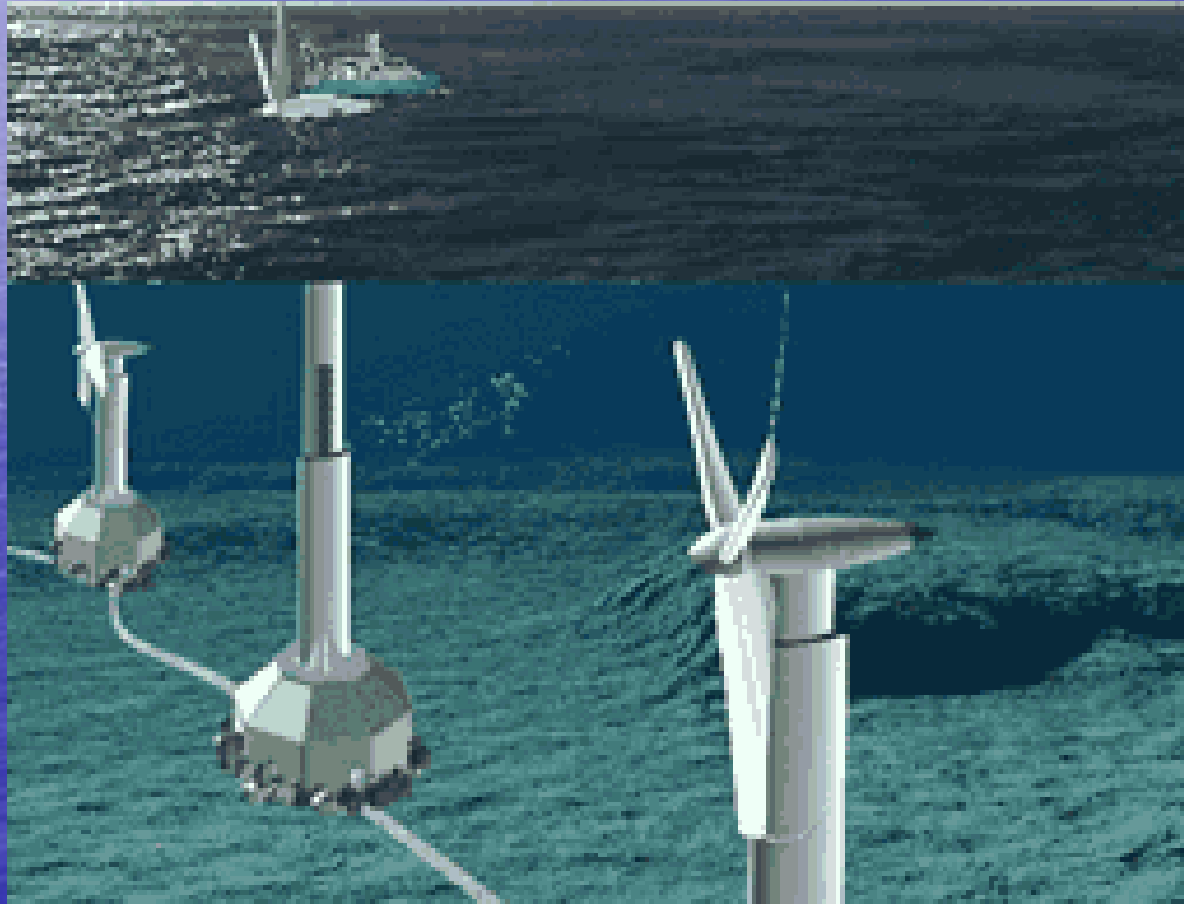


Tidal turbines



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Swan turbines



Energy from Temperature Differences

- **Ocean thermal energy conversion (OTEC)**
 - This technology is based on the temperature difference between warm surface sea water and cold, deep sea water.
 - Temperature differences of 20-25 C degrees make this possible.
 - Efficiencies are low; net efficiency is 3% using a 24 C degree gradient; 10-20 times less efficient than conventional fossil fuel plants.

OTEC Plants

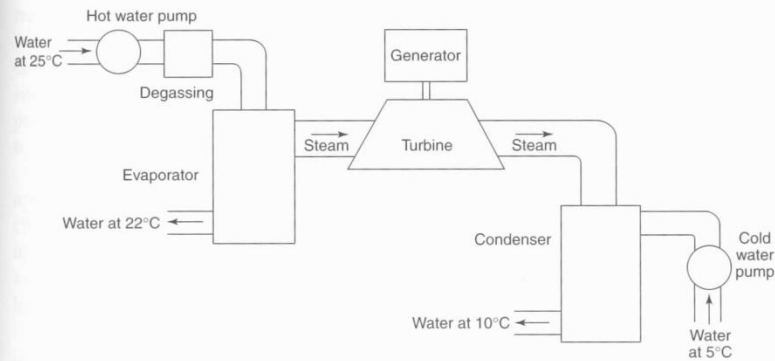


Figure 14.5a. Operating principle of an open-cycle OTEC plant. Adapted from: Brin (1981).

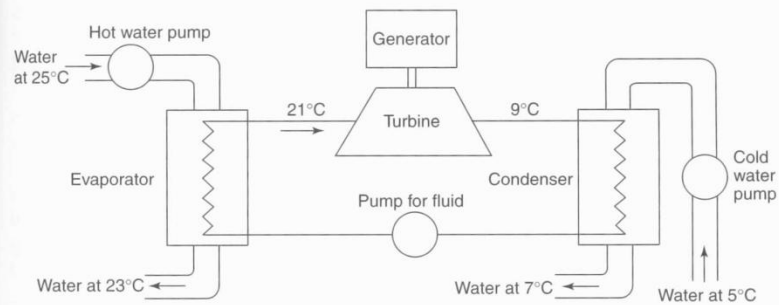


Figure 14.5b. Operating principle of a closed-cycle OTEC plant. Adapted from: Brin (1981).

Economic Prospects

- High capital costs of OTEC applications have stifled development of the technology.
- Costs of electricity are projected to be higher than fossil fuel generation:
 - Tidal 50%
 - OTEC 100%
 - Wave 150%
- Tidal barrage construction is very expensive and is delaying construction of new projects.
- OTEC has tremendous potential but is limited by the availability of good onshore sites for development.

Environmental and Sustainability Considerations

- Environmental impacts are generally benign but can be significant for certain operations:
 - Effects on migratory species at estuarine locations.
 - OTEC units may release more CO₂ to the atmosphere.
 - Navigation hazards.
 - Pathogens may be released from deep sea water brought to the surface.

The Ocean as an Externalities Sink

- Seeding of the ocean with iron or fertilizer to promote algal growth....increase the rates of carbon dioxide sequestration.
- Pump carbon dioxide into the deep ocean.
- Dispose of nuclear waste in deep sea trenches.

Current and Future Prospects

- The costs associated with global warming may make tidal/OTEC power more feasible.