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# OTEC - Ocean Thermal Energy Conversion

## INTRODUCTION

Oceans are the world's largest solar collectors. The sun's heat warms the surface water a lot more than the deep ocean water and the temperature difference creates thermal energy.

In tropical seas (e.g. India), temperature differences of about 20-25 °C may occur between the warm, solar-absorbing surface water and the cooler 500-1000 m depth water. In temperate seas (e.g. Spain) the temperature difference is less and minimal in the Arctic/Subarctic seas (e.g. Iceland).

Natural convection is a mechanism, or type of heat transport, in which the fluid motion is not generated by any external source, but only by density differences in the fluid occurring due to temperature gradients. The driving force for natural convection is buoyancy, a result of differences in fluid density.

The vertical temperature distribution in the open ocean can be described as consisting of two layers, separated by an interface. The upper layer is warmed by the sun and mixed to depths of about 100 m by wave motion. The bottom layer consists of colder water formed at high latitudes. The interface or thermocline is sometimes marked by an abrupt change in temperature but more often the change is gradual. The temperature difference between the upper (warm) and bottom (cold) layers ranges from 10°C to 25°C, with the higher values found in equatorial waters. It implies that there are two enormous reservoirs providing the heat source and the heat sink required for power engines.

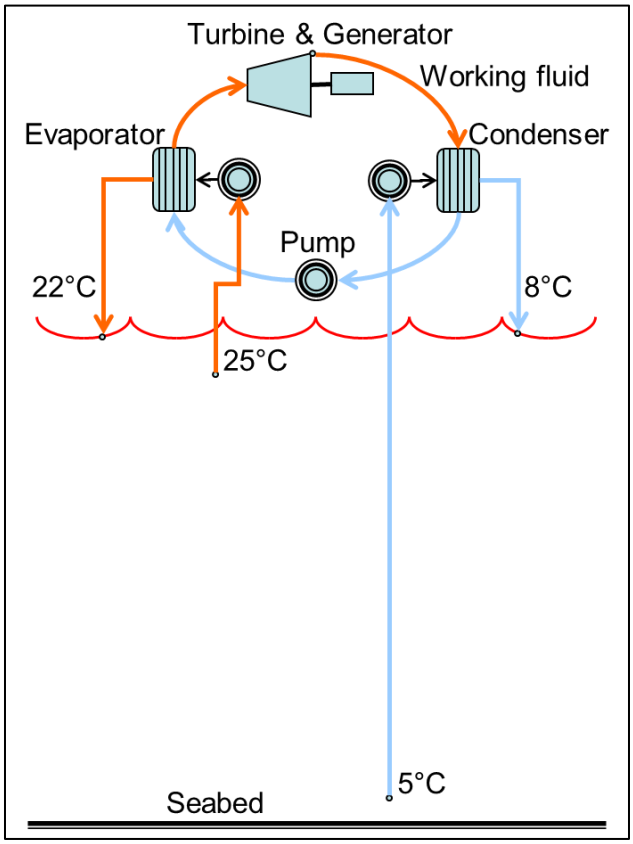
The attractiveness of OTEC for Power Production purposes is the limitless energy of hotter surface water in relation to colder deep water and its potential for constant extraction of base load electrical power. However temperature difference is very small and so the efficiency of any device for transforming this energy to mechanical power will also be very small. Moreover, large volumes of seawater need to be pumped, so reducing the net energy generated and requiring large pipes and related equipment.

It has been confirmed by other sources that cost per unit of OTEC power output is high, except perhaps on a very large scale. This has led to other justifications for pumping up the cold, deeper waters, which contain nutrients and therefore increase surface photo-synthesis of phytoplankton and hence fish population. The degree to which this has a positive or negative impact on fisheries and the ecosystem is unknown and would require studies at each site.

## OTEC Systems

OTEC system uses the temperature difference between the ocean’s warm surface and the cooler bottom water to extract heat energy that can be used to power an engine to produce electricity. The temperature difference between the surface and deep waters is generally small, approximately 20°C. Low temperature difference requires the OTEC plant to have large equipment needs, driving up the capital cost.

The figure shows a schematic of a closed cycle OTEC system. It outlines the conventional power system for OTEC in a closed cycle. Its essence is a Binary Power Plant and working fluid with a low boiling point, i.e. ammonia. In the evaporator surface water is used to heat up the working fluid. In the condenser bottom water is used to cool down the working fluid. As the working fluid expands it drives the turbine which in turn drives the electricity generator.




An alternative version of OTEC open cycle systems uses seawater as a working fluid. (Schematic not shown) Warm water from near the surface of the sea is pumped into a flash evaporator in which the pressure has been lowered to the point where the warm sea water boils at ambient temperature. This process produces steam that drives a low-pressure turbine to generate electricity. After leaving the turbine, the steam is condensed in a heat exchanger cooled by cold, deep ocean water and produces desalinated water.

## Production Cost

Example of an existing installation is the 105 kV OTEC Power Plant on Big Island Hawaii with plant cost of 5 MUSD and the cost of production in claimed to be 200-250 USD/MWh. (Reference: http://www.digitaltrends.com/cool-tech/hawaii-ocean-thermal-energy-conversion/).

With capital costs of 1.5 MUSD and specific capacity costs of 15000 USD/kW, power production costs would be approximately 200-250 USD/MWh. Therefore it could be assumed that subsidies of ca 3.5 MUSD are probably involved in the Big Island calculation of production costs. However this is only guesswork, to let the variables fit together.

## Conclusion

Big Island Hawaii is, considering OTEC, favorably located in the tropical seas.

The above calculations, along with Iceland's subarctic location, leads to the conclusion that the outlook for OTEC plants is negative for Iceland.