

Commercial Implementation Of Ocean Thermal Energy Conversion

Using the Ocean for Commercial Generation Of Baseload Renewable Energy and Potable Water

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Ocean thermal energy conversion (OTEC) is a renewable energy technology applicable to tropical and subtropical areas that works by recovering solar energy absorbed by the ocean. As opposed to other renewable technologies, such as solar and wind, OTEC generates power on a continuous (base-

load) basis. In addition, if desired, OTEC can coproduce potable water through desalination—up to two million liters per day can be produced for each megawatt of electricity generated.

OTEC requires no fuel; thus, the cost of producing electricity and water is not susceptible to the volatility that affects other energy sources like petroleum, coal and natural gas. It generates energy from purely local sources at a cost that is essentially fixed and predictable. Furthermore, since no fuels or radioactive materials are used, the environmental impacts (including greenhouse gas generation) are much less than those of conventional methods of power generation.

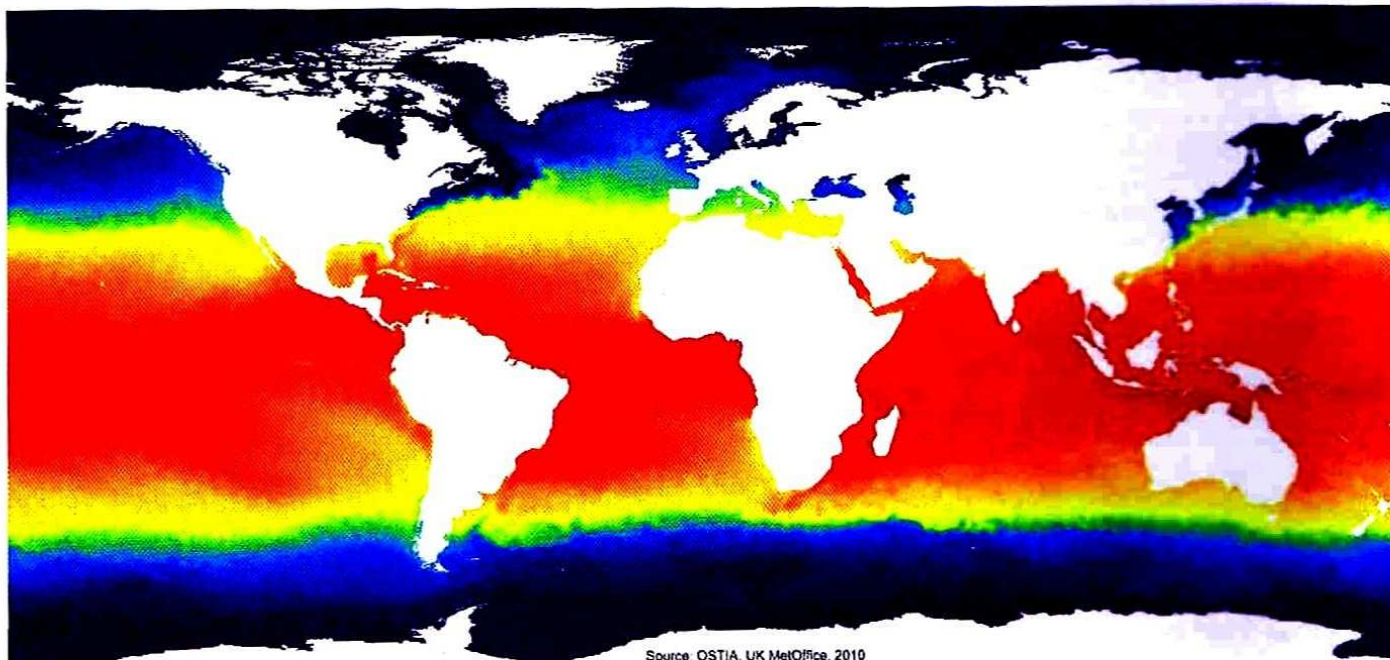
Basic Principles

OTEC plants are heat engines that convert heat into work by exploiting the

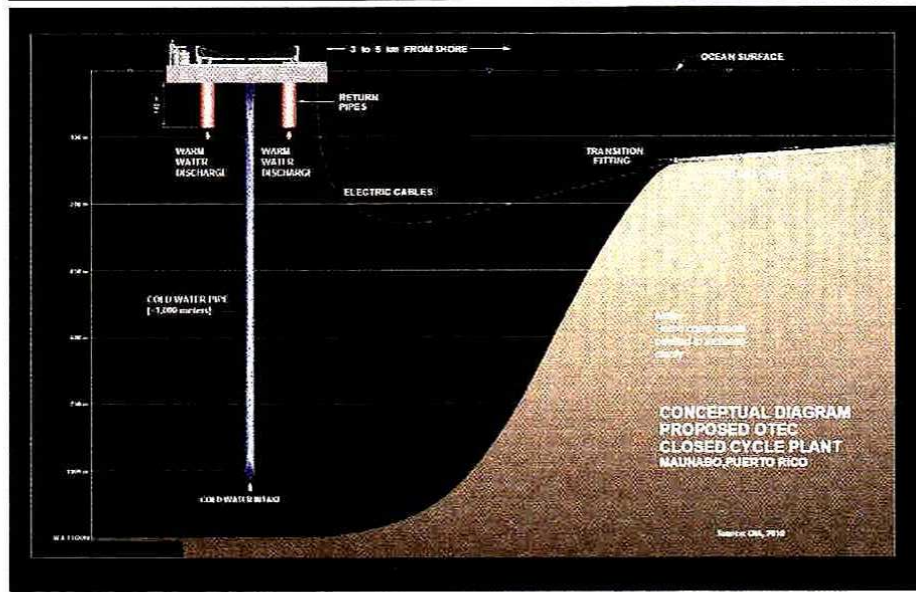
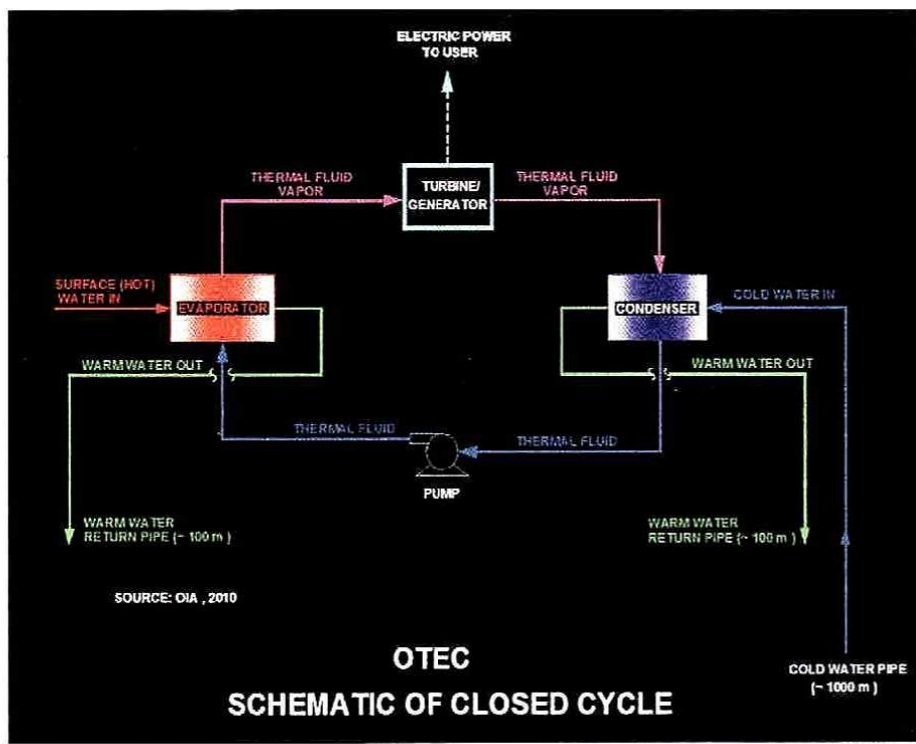
energy gradient between a “source” and a “sink.” This is similar to a steam engine, although in the case of OTEC, the temperature gradient is much smaller. This makes OTEC plants larger than steam plants of comparable capacities.

OTEC has three basic modalities: closed, open and hybrid cycles. In the closed cycle, the temperature difference is used to vaporize (and condense) a working fluid (e.g., ammonia) to drive a turbine generator to produce electricity. In the open cycle, warm surface water is introduced into a vacuum chamber where it is flash-vaporized.

Ocean surface temperatures in February of this year. OTEC is feasible in deep waters in the regions marked in yellow and red. (Courtesy of the Operational Sea Surface Temperature and Sea Ice Analysis program, U.K. Meteorological Office)



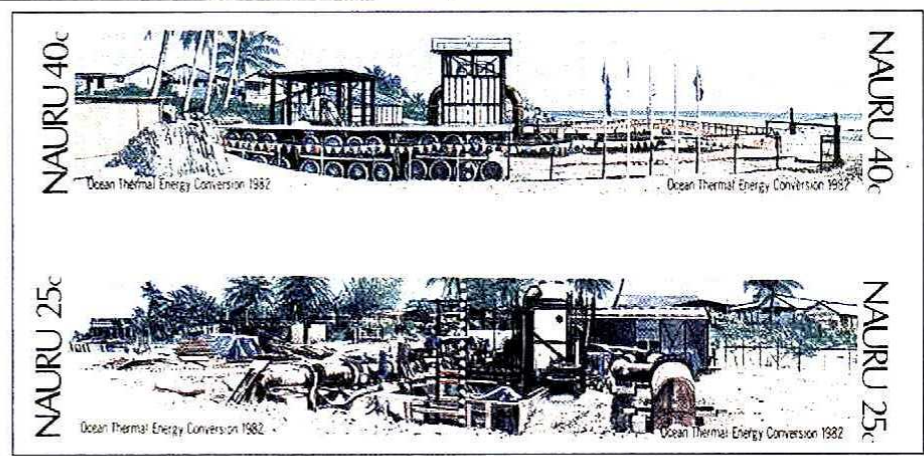
Source: OSTIA, UK MetOffice, 2010



(Above, top) Schematic of OTEC closed cycle.

(Above, bottom) Platform-mounted commercial OTEC plant proposed by OIA for Puerto Rico. Some components have been omitted for clarity.

(Right) Postal stamps commemorating the OTEC plant built for the Republic of Nauru.



This water vapor drives a turbine generator to produce electricity. The remaining water vapor (essentially distilled water) is condensed using cold sea water, and this condensed water can either return to the ocean or be collected as potable water. The hybrid cycle combines characteristics of the closed

and open cycles and has great potential for applications requiring higher efficiencies for the coproduction of energy and potable water. In all three cycles, cold ocean water, normally available at depths of 1,000 meters, where the

water temperature remains constant at around 4° C, is required to condense the working fluid.

History of OTEC

OTEC was formally proposed in 1881 by French physicist Jacques Arsène d'Arsonval, based on an idea presented by Jules Verne in the novel *20,000 Leagues under the Sea*, published in France in 1869. One of d'Arsonval's students was Dr. Georges Claude, a French engineer and businessman, often called "France's Edison." Claude began work on OTEC during the 1920s, initially conducting experiments in Belgium. In 1930, he built an OTEC open-cycle plant at Matanzas Bay in Cuba, but it only operated for a few days before being destroyed by a major storm. He made a second attempt in 1935, which consisted of a ship-mounted plant off the coast of Brazil, but this also failed due to poor weather.

During the 1950s and 1960s, a number of research and development (R&D) projects were conducted, including design proposals by the French company *Energie des Mers*, meaning "energy from the seas," and the Sea Water Conversion Laboratory at the University of California, Berkeley.

During the energy crisis of the mid-1970s, interest in OTEC increased in the United States and elsewhere. The U.S. government launched various R&D programs that included performance tests, preliminary designs and demonstration plants. Major efforts included preliminary designs for OTEC

Commercial viability depends on a number of conditions. First, technologies capable of producing baseline power at a lower cost than OTEC must not be available in the proposed location. In addition, the thermal resource must be present on a continuous basis (i.e., the temperature gradient must be equal to or greater than 20° C throughout the year) and located relatively close to shore. Finally, there must be a market for the output of the plant.

These conditions occur in developed locations that presently consume large amounts of power from fossil fuels, such as Puerto Rico and Hawaii, and also in other locations, such as smaller Caribbean and Pacific islands.

OIA estimates that power from an OTEC plant can be sold to consumers at \$0.18 per kilowatt-hour or less. More importantly, the price will be stable.

For comparison purposes, the average price of electricity in Hawaii in October 2009 was \$0.2357 per kilowatt-hour, and it had reached levels as high as \$0.3228 per kilowatt-hour the previous October due to record high oil prices in the preceding months.

In locations such as smaller Caribbean or Pacific islands that presently use small diesel plants for power—and that rely on desalination for potable water production—the economics of OTEC are even more attractive.

If renewable energy credits or other incentives are available, the economics of OTEC could be even more favorable in these areas and perhaps beyond. In addition, there would be significant benefits to the environment, since the air pollutants and greenhouse gases resulting from fuel combustion would not occur.

Acknowledgments

The authors would like to acknowledge the participation of Thomas J. Plocek, founder of OIA, who had the vision to resume work on OTEC in the early 2000s.

References

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