Open-Cycle Ocean Thermal Energy Conversion

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Fact Sheet

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In May 1983 the Florida Solar Energy Center (FSEC) received $328,000 from the federal Solar Energy Research Institute in Colorado to determine the feasibility of an Open-Cycle Ocean Thermal Energy Conversion (OTEC) concept. The objective of the project is to assess the economic and technological viability of the conceptual design of an Open-Cycle OTEC power plant. FSEC and Creare R&D Inc., Hanover, New Hampshire, bring together complementary skills and experience in resource assessment, component design, system engineering and project management. FSEC also will study possible sites for an OTEC plant in Florida as part of a complementary project funded by the coastal energy impact program through the Florida Department of Community Affairs.

OTEC Principle

Ocean Thermal Energy Conversion (OTEC) is based on the principle that a heat engine can operate between two heat sources at different temperatures and produce electricity. For OTEC the two sources are warm (80°F) tropical surface waters of the ocean and the cold (40°F) waters at depths of 3,000 feet. Because of this very small temperature difference, the theoretical maximum efficiency of OTEC is about 7 percent; the practical efficiency is about 2 percent.

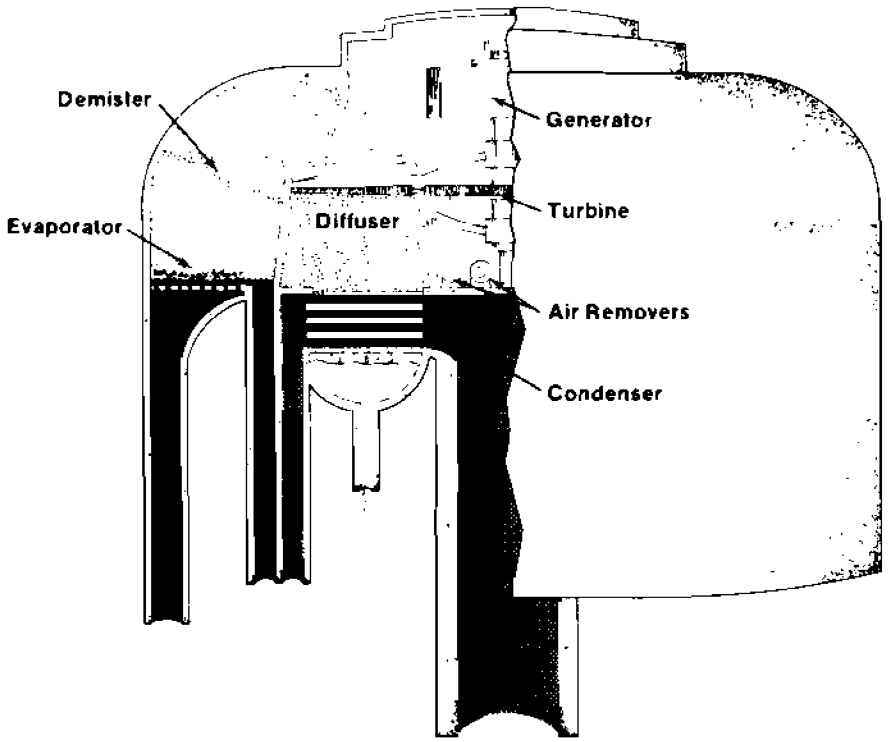

Figure 1.

Ocean Thermal Energy Conversion Pilot Plant

- Warm water is drawn into OTEC plant.
- Less than 1 percent of the water is turned into steam by the extremely low pressure in the evaporator. The remaining water is discharged. Steam turns a turbine, which causes a generator to produce electricity.
- Deep ocean water passes through pipes, which cools steam.
- The steam condenses, producing fresh water.

Thus, OTEC systems operate at a very low efficiency when compared to fossil-fired plants which have an efficiency of about 35 percent.

Because of the low efficiency involved in the OTEC concept, commercial size facilities would be quite large compared to conventional power plants. However, OTEC incurs no fuel cost; and the ocean thermal resource is vast, renewable, and virturally limitless. The ocean also stores the sun's energy received during the day, thus providing its own storage system and making possible baseload power generation (to satisfy continuous demand).

System:

The Open-Cycle system (Figure 1) uses seawater as the working fluid. Warm surface water is evaporated in a flash evaporator (where water is evaporated at very low pressure), producing low pressure steam, which then drives a turbine and generator to produce electricity. The steam is cooled in the condenser by the deep cold seawater. If a surface condenser is used (keeping the condensate and the cooling waters separate), then fresh water is also produced.

OTEC Applications

1. Open-Cycle systems can produce fresh water.
2. Cold water brought to the surface by all OTEC plants is nutrient-rich and suitable for marine aqua culture.
3. With energy provided by OTEC, hydrogen and oxygen can be produced by electrolyzing water; ammonia and, thus, fertilizers, can be produced by combining this hydrogen with nitrogen from the air.
4. Synthetic fuels such as methane, methanol, or those made from carbon resources transported to the OTEC platform are other possible products.
5. OTEC energy could also be transmitted to shore in molten salt or lithium-air storage systems, or used to refine metals such as aluminum, iron, or magnesium from new materials brought to the ocean plant.

Potential Resources

The best OTEC resources are found year-round in the tropics north and south of the equator and near parts of Florida's coast. Table 1 shows the gross temperature resources available for selected U.S. and world sites. It is estimated that over 20 million square miles (52 million square kilometers) of suitable ocean area exist worldwide for OTEC sites with the upper extractable limit of this resource being about 200 quads or 2,200,000 MW, which is the equivalent to 39.6 million barrels of oil per day. Potential OTEC sites off the continental U.S. include the Florida Gulf Stream and the Gulf of Mexico. Other areas of interest include Puerto Rico, the Virgin Islands, Guam, Hawaii, and the U.S. trust territory of the Pacific Islands. Other factors to be considered in actual site selection include such resource limitations as heavy storm seasons, strong currents, very deep cold water, and rough ocean bottom conditions. Because of the low efficiency of OTEC systems, they are very sensitive to changes in termperature differences. A 1.8°F (1°C) decrease in temperature difference caused by storm conditions or thermal degradation will decrease the net output by 12 percent. Also, biofouling accumulations (primary slimes) in the heat exchangers will reduce heat transfer and therefore reduce the power output. Nonetheless, estimates indicate OTEC's worldwide potential of thousands of gigawatts of power.

Table 1
Temperature resources at key U.S. and world sites

	Mean annual delta T (°F/°C)	delta T in coldest month (°F/°C)
Florida East Coast	37.1/20.6	33.7/18.7
Key West	36.2/20.1	31.3/17.4
Eastern Gulf of Mexico	40.7/22.6	37.6/20.9
Northern Gulf of Mexico	37.8/21.0	28.8/16.0
Western Gulf of Mexico	37.1/20.6	29.3/16.3
Hawaii (Keahole Point)	38.5/21.4	36.0/20.0
Puerto Rico (Punta Tuna)	40.1/22.3	37.6/20.9
Central Pacific	41.4/23.0	40.5/22.5
West Pacific	45.0/25.0	44.3/24.6
Equator East Pacific	36.9/20.5	35.1/19.5
Guam	43.4/24.1	42.1/23.4
Brazil (S. Atlantic)	39.8/22.1	38.2/21.2
NW Australia	40.7/22.6	37.3/20.7
Manila	43.2/24.0	40.7/22.6

Summary

Some of the significant findings and important conclusions about OTEC are as follows:

1) No major technical breakthroughs are required but some important developments are indeed needed.

2) OTEC is potentially cost competitive with coal, oil, and nuclear energy.

3) Open-Cycle OTEC can produce fresh water substantially more economically than by desalination.

4) OTEC provides an enormous source of environmentally benign power.

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