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A Review of Ocean Thermal Energy Conversion

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Abstract

Oceans cover more than 70% of the Earth's surface. As the world's largest solar collectors, oceans generate thermal energy from the sun. They also produce mechanical energy from the tides and waves. Even though the sun affects all ocean activity, the gravitational pull of the moon primarily drives the tides, and the wind powers the ocean waves. This makes them the world's largest solar energy collector and energy storage system. On an average day, 60 million square kilometers (23 million square miles) of tropical seas absorb an amount of solar radiation equal in heat content to about 250 billion barrels of oil. If less than one-tenth of one percent of this stored solar energy could be converted into electric power, it would supply more than 20 times the total amount of electricity consumed in the United States on any given day. OTEC, or ocean thermal energy conversion, is an energy technology that converts solar radiation to electric power. OTEC systems use the ocean's natural thermal gradient—the fact that the ocean's layers of water have different temperatures—to drive a power-producing cycle. As long as the temperature between the warm surface water and the cold deep water differs by about 20°C (36°F), an OTEC system can produce a significant amount of power. The oceans are thus a vast renewable resource, with the potential to help us produce billions of watts of electric power. This potential is estimated to be about 1013 watts of baseload power generation, according to some experts. The cold, deep seawater used in the OTEC process is also rich in nutrients, and it can be used to culture both marine organisms and plant life near the shore or on land. The economics of energy production today have delayed the financing of a permanent, continuously operating OTEC plant. However, OTEC is very promising as an alternative energy resource for tropical island communities that rely heavily on imported fuel. OTEC plants in these markets could provide islanders with much-needed power, as well as desalinated water and a variety of Mari-culture products.

Keyword- Ocean Thermal Energy Conversion (OTEC), Cycle Types

I. PLANT DESIGN AND LOCATION

Commercial ocean thermal energy conversion (OTEC) plants must be located in an environment that is stable enough for efficient system operation. The temperature of the warm surface seawater must differ about 20°C (36°F) from that of the cold deep water that is no more than about 1000 meters (3280 feet) below the surface. The natural ocean thermal gradient necessary for OTEC operation is generally found between latitudes 20 deg N and 20 deg S. Within this tropical zone are portions of two industrial nations—the United States and Australia—as well as 29 territories and 66 developing nations. Of all these possible sites, tropical islands with growing power requirements and a dependence on expensive imported oil are the most likely areas for OTEC development.

Commercial OTEC facilities can be built on

- Land or near the shore
- Platforms attached to the shelf
- Moorings or free-floating facilities in deep ocean water

A. Land-Based and Near-Shore Facilities

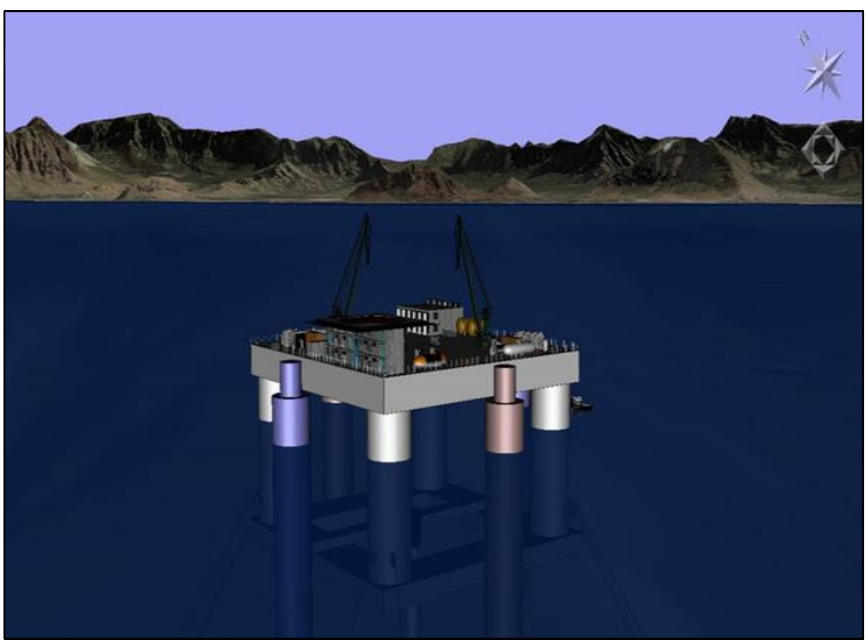
Land-based and near-shore facilities offer three main advantages over those located in deep water. Plants constructed on or near land do not require sophisticated mooring, lengthy power cables, or the more extensive maintenance associated with open-ocean environments. They can be installed in sheltered areas so that they are relatively safe from storms and heavy seas. Electricity, desalinated water, and cold, nutrient-rich seawater could be transmitted from near-shore facilities via trestle bridges or causeways. In addition, land-based or near-shore sites allow OTEC plants to operate with related industries such as Mari culture or those that require desalinated water.

Land-based or near-shore sites can also support Mari culture. Mari culture tanks or lagoons built on shore allow workers to monitor and control miniature marine environments. Mari culture products can be delivered to market with relative ease via railroads or highways.

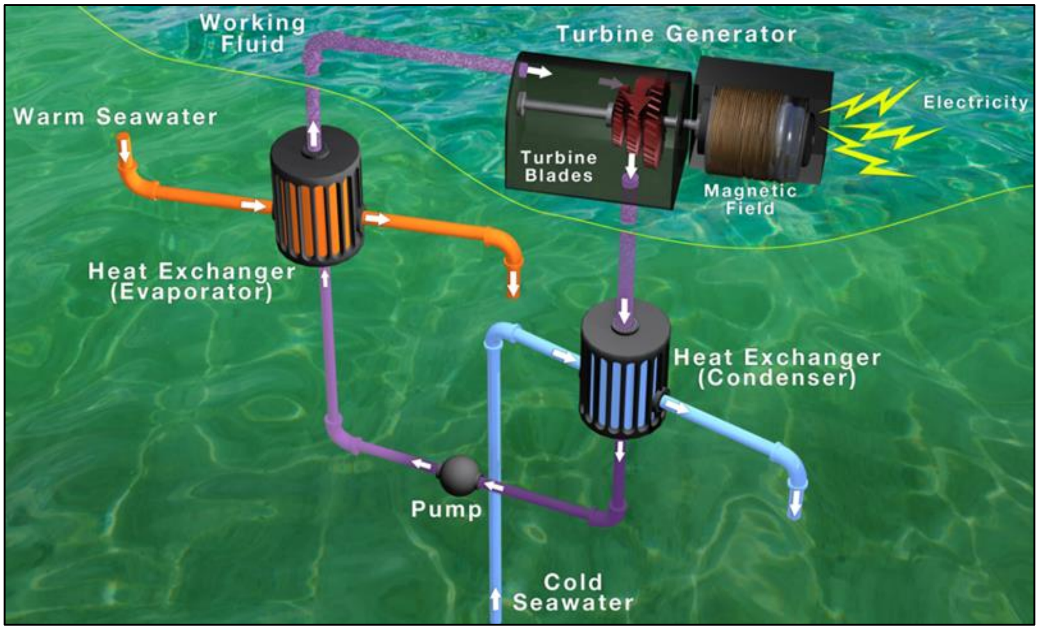
One disadvantage of land-based facilities arises from the turbulent wave action in the surf zone. Unless the OTEC plant's water supply and discharge pipes are buried in protective trenches, they will be subject to extreme stress during storms and prolonged periods of heavy seas. Also, the mixed discharge of cold and warm seawater may need to be carried several hundred meters offshore to reach the proper depth before it is released. This arrangement requires additional expense in construction and maintenance.

B. Shelf-Mounted Facilities

To avoid the turbulent surf zone as well as to have closer access to the cold-water resource, OTEC plants can be mounted to the continental shelf at depths up to 100 meters. A shelf-mounted plant could be built in a shipyard, towed to the site, and fixed to the sea bottom. This type of construction is already used for offshore oil rigs. The additional problems of operating an OTEC plant in deeper water, however, may make shelf-mounted facilities less desirable and more expensive than their land-based counterparts. Problems with shelf-mounted plants include the stress of open-ocean conditions and more difficult product delivery. Having to consider strong ocean currents and large waves necessitates additional engineering and construction expense. Platforms require extensive pilings to maintain a stable base for OTEC operation. Power delivery could also become costly because of the long underwater cables required to reach land. For these reasons, shelf-mounted plants are less attractive for near-term OTEC development.



II. WORKING



The system work as like that of thermal power plant. Initially the warm sea water passing in to the heat exchanger then the sea water is evaporated by the heat exchanger. The evaporated water is passing to the turbine through the nozzle. The nozzle is used to force the stream.

The force water is fall on the turbine blade and made it to rotate. The turbine blade is connected with the turbine generator through the shaft. Then the electricity is produced. Then the water is recycled through the condenser.

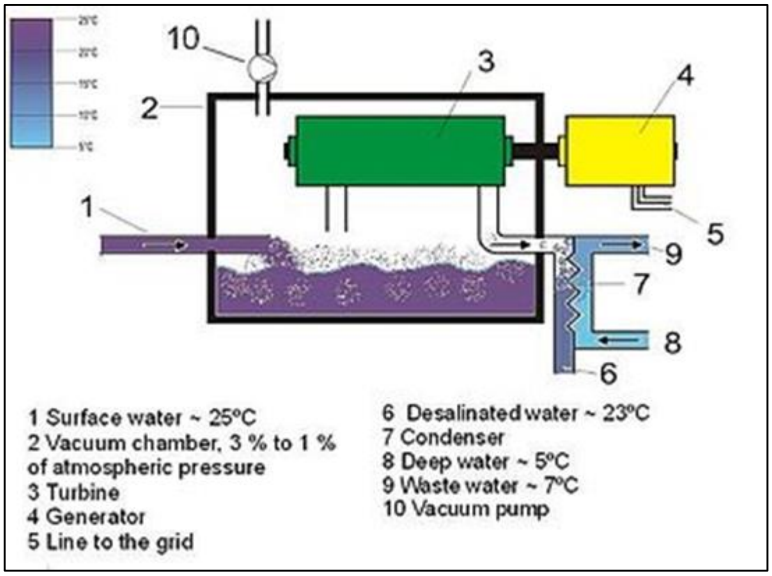
III. CYCLE TYPES

Cold seawater is an integral part of each of the three types of OTEC systems: closed-cycle, open-cycle, and hybrid. To operate, the cold seawater must be brought to the surface. The primary approaches are active pumping and desalination. Desalinating seawater near the sea floor lowers its density, which causes it to rise to the surface.

- Open cycle
- Closed cycle
- Hybrid cycle

These are the main thing to produce the electricity.

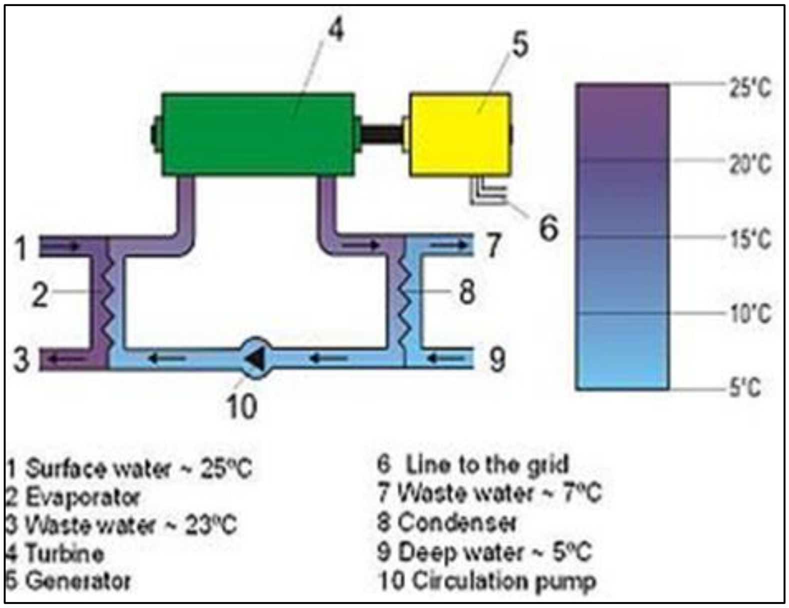
A. Open Cycle



Open-cycle OTEC uses warm surface water directly to make electricity. Placing warm seawater in a low-pressure container causes it to boil. The expanding steam drives a low-pressure turbine attached to an electrical generator. The steam, which has left its salt and other contaminants in the low-pressure container, is pure fresh water. It is condensed into a liquid by exposure to cold temperatures from deep-ocean water. This method produces desalinized fresh water, suitable for drinking water or irrigation.[13]

In 1984, the Solar Energy Research Institute (now the National Renewable Energy Laboratory) developed a vertical-spout evaporator to convert warm seawater into low-pressure steam for open-cycle plants. Conversion efficiencies were as high as 97% for seawater-to-steam conversion (overall efficiency using a vertical-spout evaporator would still only be a few per cent). In May 1993, an open-cycle OTEC plant at Keahole Point, Hawaii, produced 50,000 watts of electricity during a net power-producing experiment.[14] This broke the record of 40 kW set by a Japanese system in 1982.[14]

B. Closed Cycle

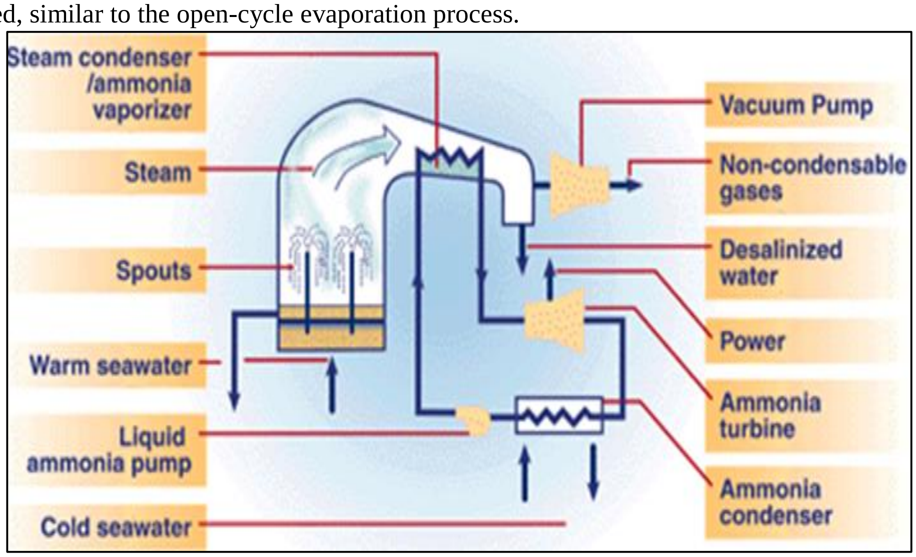


Closed-cycle systems use fluid with a low boiling point, such as ammonia, to power a turbine to generate electricity. Warm surface seawater is pumped through a heat exchanger to vaporize the fluid. The expanding vapor turns the turbo-generator. Cold water, pumped through a second heat exchanger, condenses the vapor into a liquid, which is then recycled through the system.

In 1979, the Natural Energy Laboratory and several private-sector partners developed the "mini OTEC" experiment, which achieved the first successful at-sea production of net electrical power from closed-cycle OTEC.[12] The mini OTEC vessel was moored 1.5 miles (2.4 km) off the Hawaiian coast and produced enough net electricity to illuminate the ship's light bulbs and run its computers and television.

C. Hybrid Cycle

A hybrid cycle combines the features of the closed- and open-cycle systems. In a hybrid, warm seawater enters a vacuum chamber and is flash-evaporated, similar to the open-cycle evaporation process.



The steam vaporizes the ammonia working fluid of a closed-cycle loop on the other side of an ammonia vaporizer. The vaporized fluid then drives a turbine to produce electricity. The steam condenses within the heat exchanger and provides desalinated water. (sea heat pipe)

IV. NEEDED RESEARCH

To accelerate the development of OTEC systems, researchers need to:

- Obtain data on OTEC plant operation with appropriately sized demonstration plants
- Develop and characterize cold-water pipe technology and create a database of information on materials, design, deployment, and installation
- Conduct further research on the heat exchanger systems to improve heat transfer performance and decrease costs
- Conduct research in the areas of innovative turbine concepts for the large machines required for open-cycle systems
- Identify and evaluate advanced concepts for ocean thermal energy extraction

V. BENEFITS OF OTEC

We can measure the value of an ocean thermal energy conversion (OTEC) plant and continued OTEC development by both its economic and noneconomic benefits. OTEC's economic benefits include these:

- Helps produce fuels such as hydrogen, ammonia, and methanol
- Produces base load electrical energy
- Produces desalinated water for industrial, agricultural, and residential uses
- Is a resource for on-shore and near-shore mariculture operations
- Provides air-conditioning for buildings
- Provides moderate-temperature

OTEC's noneconomic benefits, which help us achieve global environmental goals, include these:

- Promotes competitiveness and international trade
- Enhances energy independence and energy security
- Promotes international socio-political stability
- Has potential to mitigate greenhouse gas emissions resulting from burning fossil fuels.

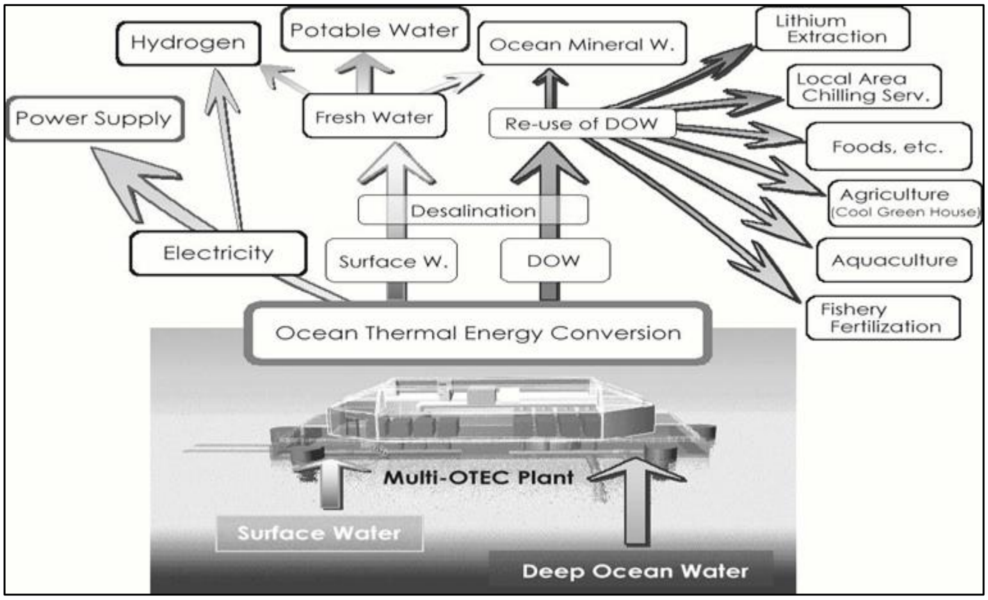
In small island nations, the benefits of OTEC include self-sufficiency, minimal environmental impacts, and improved sanitation and nutrition, which result from the greater availability of desalinated water and mariculture products.

VI. MARKETS FOR OTEC

An economic analysis indicates that, over the next 5 to 10 years, ocean thermal energy conversion (OTEC) plants may be competitive in four markets. The first market is the small island nations in the South Pacific and the island of Molokai in Hawaii. In these islands, the relatively high cost of diesel-generated electricity and desalinated water may make a small [1 megawatt (electric) (MWe)], land-based, open-cycle OTEC plant coupled with a second-stage desalinated water production system cost effective. A second market can be found in American territories such as Guam and American Samoa, where land-based, open-cycle OTEC plants rated at 10 MWe with a second-stage water production system would be cost effective. A third market is Hawaii, where a larger, land-based, closed-cycle OTEC plant could produce electricity with a second-stage desalinated water production system. OTEC should quickly become cost effective in this market, when the cost of diesel fuel doubles, for plants rated at 50 MWe or larger. The fourth market is for floating, closed-cycle plants rated at 40 MWe or larger that house a factory or transmit electricity to shore via a submarine power cable. These plants could be built in Puerto Rico, the Gulf of Mexico, and the Pacific, Atlantic, and Indian Oceans. Military and security uses of large floating plant ships with major life-support systems (power, desalinated water, cooling, and aquatic food) should be included in this last category.

OTEC's greatest potential is to supply a significant fraction of the fuel the world needs by using large, grazing plant ships to produce hydrogen, ammonia, and methanol. Of the three worldwide markets studied for small OTEC installations—U.S. Gulf Coast and Caribbean regions, Africa and Asia, and the Pacific Islands—the Pacific Islands are expected to be the initial market for open-cycle OTEC plants. This prediction is based on the cost of oil-fired power, the demand for desalinated water, and the social benefits of this clean energy technology. U.S. OTEC technology is focused on U.S. Coastal areas, including the Gulf of Mexico, Florida, and islands such as Hawaii, Puerto Rico, and the Virgin Islands.

VII. APPLICATIONS



Ocean thermal energy conversion (OTEC) systems have many applications or uses. OTEC can be used to generate electricity, desalinate water, support deep-water mariculture, and provide refrigeration and air-conditioning as well as aid in crop growth and mineral extraction. These complementary products make OTEC systems attractive to industry and island communities even if the price of oil remains low.

OTEC can also be used to produce methanol, ammonia, hydrogen, aluminum, chlorine, and other chemicals. Floating OTEC processing plants that produce these products would not require a power cable, and station-keeping costs would be reduced.

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