OTEC - Ocean Thermal Energy Conversion

By Maria Bechtel and Erik Netz

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Summary

OTEC, 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 OTEC process consist of pumping cold ocean water to the surface and using the temperature difference between this and the warm surface water to run a thermal engine to generate electricity. Producing electricity is not the only thing that OTEC can do. You can, if you want, reduce the amount of electric power and produce fresh water instead. This can be very significant on for example islands where fresh water is limited. OTEC uses water from the bottom of the sea, which is nutritious, one result of this is that a lot of fish and other seafood will be collected in the outlet flow. This means that OTEC not only produce electricity, it produces water and food too.

Introduction

The oceans cover a little more then 70 percent of the earth surface. This makes it the world's largest solar energy collector and energy storage system. On an average day, 60 million square kilometres 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 State (263 million inhabitants) on one day.

The history of Mankind, have depended upon its ability to conquer the forces of nature, and to utilise these forces to serve its needs. Energy technology is certainly one of the most important factors in the emergence of Mankind as the dominant species of this planet. The invention of the practical steam engine by James Watt, brought about development of large factories, steamships and the steam locomotive. First wood was used, then coal. About the same time, the use of coal instigated advances in metallurgy, which brought about large quantities of cheap steel and copper. This period was the beginning of the Industrial Revolution.

Petroleum from natural seepage has been used since ancient times for lighting, lubrication and waterproofing. The introduction of drilling for oil greatly increased the supply of oil. The Industrial Revolution switched into high gear. One problem is that the natural seepage is limited and in a few years the elements will be used.

The development of nuclear power was touted as the answer to all of Mankind's energy woes. It not turned out that way. The Urals Catastrophe, the Three Mile Island problem and the Chernobyl disaster have brought home forcefully the risk involved. In addition, the elimination of government subsidies for nuclear power plants has made

them quite unaffordable. When it went so bad no insure in the world will write disaster insurance for nuclear power plant.

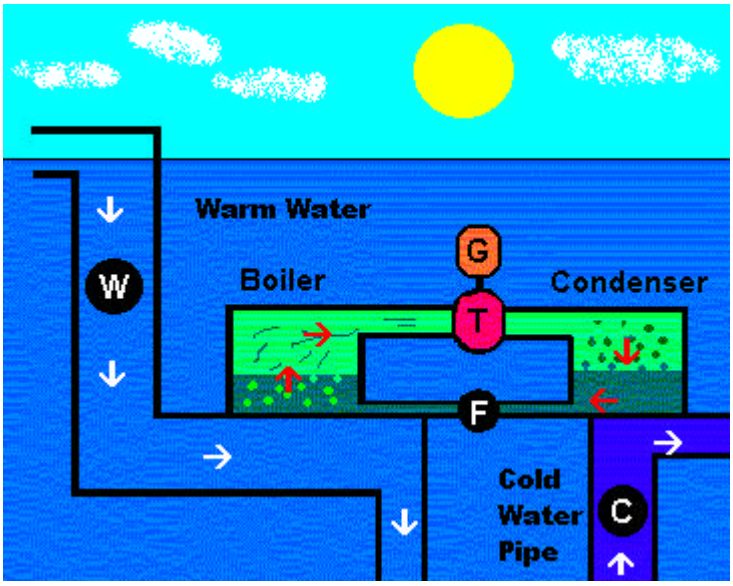
The concept of OTEC (Ocean Thermal Energy Conversion) has existed for over a century as fantasised by Jules Verne in 1870 and conceptualised by French physicist, Jacques Arsene d'Arsonval, in 1881.Despite this an operating OTEC power facility was not developed until the 1920's.

What is OTEC?

OTEC, Ocean Thermal Energy Conversion is an energy technology that converts solar radiation to electric power. OTEC systems use the ocean's natural thermal gradient, consequently the temperature difference between the warm surface water and the cold deep water below 600 meters by about 20°C, 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. The cold 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 total influx of solar energy into the earth is of thousands of times as great as Mankind's total energy use. All of our coal, oil and natural gas are the result of the capture of solar energy by life of the past. There have been many projects for harnessing solar energy, but most have not been successful because they attempt to capture the energy directly. The problem with this is that huge collectors must be deployed to do this, and resulting in large costs. The idea behind OTEC is the use of all natural collectors, the sea, instead of artificial collector.

How does it work in eal life?



Warm water is collected on the surface of the tropical ocean and pumped by a warm water pump. The water is pumped through the boiler, where some of the water is used to heat the working fluid, usually propane or some similar material. If it is cooler you can use a material with a lower boiling point like ammonia. The propane vapour expands trough a turbine which is coupled to a generator that generating electric power. Cold water from the bottom is pumped through the condensers, where the vapour returns to the liquid state. The fluid is pumped back into the boiler.

Some small fraction of the power from the turbine is used to pump the water through the system and to power other internal operations, but most of it is available as net power.

There are two different kind of OTEC power plants, the Land based and the floating plant.

Land-based powerplant:

The land based pilot plant will consist of a building. This building will contain the heat exchangers, turbines, generators and controls. It will be connected to the ocean via several pipes, and an enormous fish farm (100 football arenas) by other pipes.

Warm water is collected through a screened enclosure close to the shore. A long pipe laid on the slope collects cold water. Power and fresh water are generated in the building by the equipment. Used water is first circulated into the marineculture pond (fish farm) and then discharges by the third pipe into the ocean, downstream from the warm water inlet. This is done so that the outflow does not reenter the plant, since re-use of warm water would lower the available temperature difference.

Floating powerplant:

The floating powerplant works in the same way as the landbased the apparent

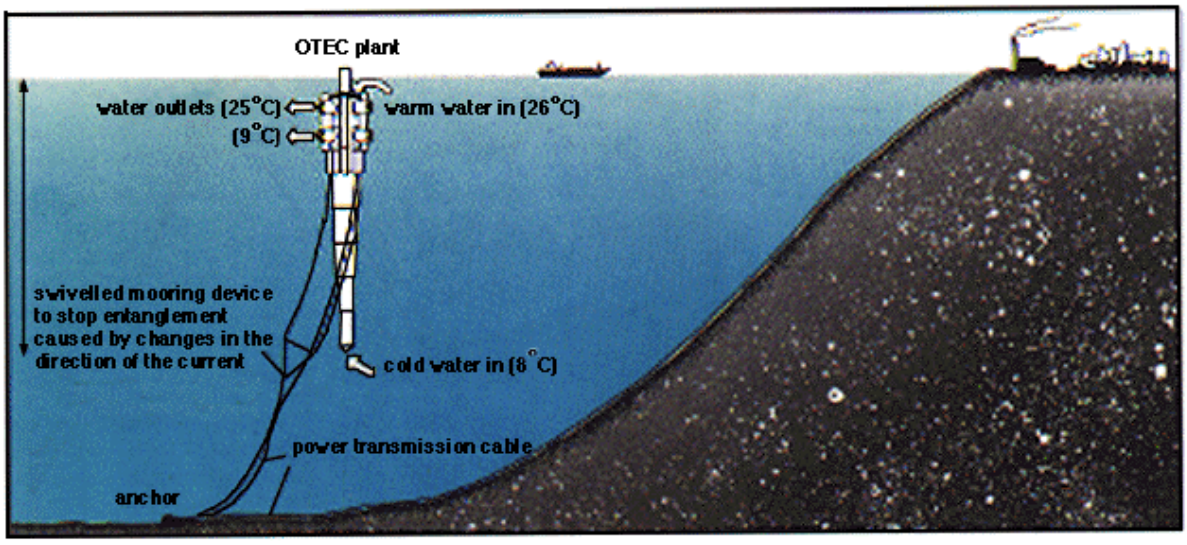


Figure 2.10 A general view of the proposed OTEC plant which would use the difference in temperature between the surface of the ocean and deep waters to obtain electrical energy. As much as 160 000 kW might be generated by such a plant.

difference is that the floating plant is floating.

Land-based or floating plant?

The largest single item in the land based plant design is the cold water pipe. This is because slopes are seldom larger than 15° or so. This means that the length of a pipe to go down 1000 meters is equal to (1000/sin15°) which turns out to be 3864 meters. This is very large. One problem is that the pipe will be as large as 9 to 15 meters. A floating plant can have a vertical cold water pipe, which only need to be1000 meters. The fundamental reason why a land based plant costs 3 times as much per unit power output, as a sea-based plant is the expense of the cold water pipe.

One advantage with the Land based power plant is that you can easier use some of the by-products without any expensive transports. For example using the cold deep water as a fluid in air condition system. It is also cheaper to support the landbased plant.

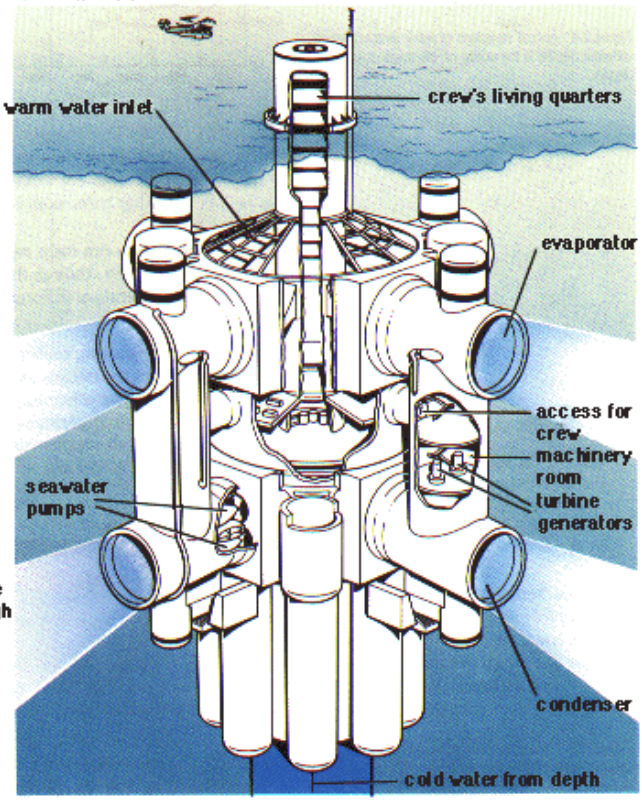


Figure 2.11 Details of the 'operating head' of an OTEC plant. Warm surface water at 26°C would be passed through the evaporators and used to vaporize propane or ammonia. This vapour would be used to drive turbines and and thus generate electricity before being passed through condensers and cooled by cold deep water.

Closed-cycle, open-cycle and hybrid-cycle

There are three types of OTEC designs: open cycle, closed cycle, and hybrid cycle. In an open cycle, seawater is the working fluid. Warm seawater is pumped into a flash evaporator where pressure as low as 0.03 bar cause the water to boil at temperatures of 22ºC. This steam expands through a low-pressure turbine connected to a generator to create power. The steam then passes through a condenser using cold seawater from the depths of the ocean to condense the steam into desalinised water.

In a closed cycle, a low boiling point liquid such as ammonia or another type of refrigerant is used as the working fluid in a Rankine cycle (common steam cycle). The heat from warm seawater flowing through an evaporator vaporises the working fluid. The vapour expands through a turbine, then flows into a condenser where cold seawater condenses it into a liquid.

A hybrid cycle is a combination of both closed and open cycles where flash evaporator seawater is used as the closed cycle working fluid.

Where can OTEC be used?

OTEC can be sited anywhere across about 60 million square kilometres of tropical oceans-anywhere there is deep cold water lying under warm surface water. This generally means between the Tropic of Cancer and the Tropic of Capricorn. Surface water in these regions, warmed by the sun, generally stays at 25 degrees Celsius or above. Ocean water more than 1,000 meters below the surface is generally at about 4 degrees C.
It would not be profitable to use an OTEC power plant in the Baltic Sea, because the average temperature is about 8-10ºC.

How effective is an OTEC powerplant?

Theoretical, it is possible to convert the energy in a 23-temperature difference at an efficiency of 7-8%. In actual practice, it is possible to do this at slightly more than 3% efficiency. This not influence that the amount of power available is small, or that power generated for this source need be expensive. This energy is equivalent to the same amount of water passing through a hydroelectric dam with a water height of 56 meters. (In other words, an OTEC plant needs to handle no more water than a hydroelectric plant of the same capacity.) This temperature difference is constantly renewed by the action of the sun and the ocean currents, and is therefore inexhaustible. The amount of water constantly available for this use is enough to provide at least 300 times Mankind's total power usage. One notice, the steam locomotives, which were used during the middle of the 19th century, had a thermal efficiency of only about 3%.

To count this efficiency you can use an equation, which is called the Carnot factor, and can be presented like this:

$$W = \frac{T - T_0}{T} * Q$$

W	=	Work (exergy)
T	=	The surface water temperature
T_0	=	The deep water temperature
Q	=	Thermal value

And if you use the values, surface temperature 27°C and deep temperature 4°C, the equation looks like this:

$$W = \frac{27 - 4}{(273 + 27)} * Q = \frac{23}{300} * Q \quad 7{,}6\% * Q$$

And as you can see the efficiency is about 7% to 8%. But as we said earlier it’s only the theoretical efficiency. The efficiency in the Baltic Sea would be 1,4%.

What can you use OTEC for besides produce electricity?

Fresh Water & Sea Food.

As the peoples of the world grown more prosperous, there will be a demand for higher quality food. Industry agriculture and commerce will require more fresh water. It is possible to use this resource to produce fresh water instead of producing electric power if there is a large ask for fresh water. The fresh water appearances when the cold water is put into contact with the vapour from the warm water stream in a large box. The vapours condense on the secondary heat exchangers, leaving the salt behind the warm water stream. The yield of fresh water from a 100-megawatt power plant would be approximately 33,000,000 cubic meter per year, comparable to a flow of a medium-sized river. This is enough to support the city of Norrköping with water during a whole year. This water is completely salt-free, suitable for all agricultural, commercial, industrial and domestic uses. Besides desalinised water you also can get by-products as ammonia, methanol. Hydrogen can be electrolysed from seawater and mixed with nitrogen to from ammonia for easy transportation from the floating plants

OTEC plant it will stimulate the growth of all kinds of seafood. Green algae (phytoplankton) in the surface waters absorb soluble nitrogen and phosphorous compounds as the engage in photosynthesis. These green algae are either eaten by animals, or die from other causes. The waste from the grazers and their carcasses, combined with the bodies of dead phytoplankton sink slowly to the bottom, carrying with them most of the soluble nitrogen and phosphorous. This is released in deep water as the detritus decomposes. This results in the enrichment of the cold deep waters with essential mineral nutrients in much higher concentration than surface waters. When the spent cold waters are released near the surface by the action of a power plant, they become an artificient upwelling, similar in effect to the great natural upwellings which are the world’s great fisheries. The reality of this phenomenon has been shown in several fish farms that have used cold bottom water as a medium. The amount of food that can be produced in this way is very large, larger in market value than the electric power produced by the plant.

You can also use the cold water as a fluid in air condition systems. Because the temperature is only a few degrees.

How much does an OTEC powerplant cost?

The prize of the first 10-megawatt land based plant is $40,000,000; including development costs and will produce profits of some $10,000,000 per year, which means a return of 25%. The prize of the first 100-megawatt floating plant will cost $215,000,000 and will yield profits of some $100,000,000 per year from sale of power, fresh water and seafood

As you can see the power plant will make profit within a period of 5 years.

To get more prizes or details about the different parts of incomes visit the WebPages: **www.seasolarpower.com**

Advantages & Disadvantages

Advantages

1. OTEC uses clean, renewable, natural resources. Warm surface seawater and cold water from the ocean depths replace fossil fuels to produce electricity.

2. Suitably designed OTEC plants will produce little or no carbon dioxide or other polluting chemicals.

3. OTEC systems can produce fresh water as well as electricity. This is a significant advantage in island areas where fresh water is limited.

4. There is enough solar energy received and stored in the warm tropical ocean surface layer to provide most, if not all, of present human energy needs.

5. The use of OTEC as a source of electricity will help reduce the state's almost complete dependence on imported fossil fuels.

Disadvantages

1. OTEC-produced electricity at present would cost more than electricity generated from fossil fuels at their current costs.

2. OTEC plants must be located where a difference of about 20º C occurs year round. Ocean depths must be available fairly close to shore-based facilities for economic operation. Floating plant ships could provide more flexibility.

3. No energy company will put money in this project because it only had been tested in a very small scale.

4. Construction of OTEC plants and lying of pipes in coastal waters may cause localised damage to reefs and near-shore marine ecosystems.

Environment

One of the most critical problems of the next century will certainly be global warming. OTEC is unique among all energy generation the technologies in that not only does it generate no carbon dioxide whatsoever, but it actually counteracts the effects of fossil fuel use. OTEC involves bringing up mineral-rich water from the depths of the oceans. This water will promote growth of photosynthetic phytoplankton. These organisms will absorb carbon dioxide from the atmosphere into their bodies, and when they die, or when the animals, which eat them, die, the carbon dioxide will be sequestered in the depths of the oceans. The effect is not small. Each 100-megawatt OTEC plant will cause the absorption of an amount of carbon dioxide equivalent to that produce by fossil fuel power plant of roughly the same capacity. No other energy technology ever imagined can do this. OTEC plants construction, with laying pipes in coastal waters may cause localised damage to reefs and near-shore marine ecosystems.

Experiments

OTEC power plants have been tested in Japan and Hawaii, and they produce 240 kW. This is only an experimental plant in a smaller scale, it will be larger in the future. Is very expensive to build a big prototype (100 MW) when you cant sale it.

ABB

Does ABB Alstom Power have a chance to develop in this area?

At presently the OTEC power plant concept is not of interest for ABB Alstom Power, however, in the future the turbine section might be an area for ABB to commercialise. Remaining parts of the OTEC plant is not within their branch of knowledge.

Conclusion

Using the temperature difference in the oceans in not a new idea. People have been talked about this for over hundred years. This piece is written by Jules Verne, from the book ”Twenty Thousands Leagues Under the Sea”.

I was determined to seek from the sea alone the means of producing my electricity. From the sea? Yes, Professor, and I was at no loss to find these means. It would have been possible, by establishing a circuit between two wires plunged to different depths, to obtain electricity by the difference of temperature to which they would have been exposed...

The fossil fuels will in the near future be consumed, so we had to find some alternative energy sources. OTEC is a source, which uses the renewable solar collector the sea, instead of an artificial collector. This can in the future be an alternative to the nuclear power and the fossil fuels. The problem is that this invention will be more expensive than the fossil fuels power plants, and it will take a long time before anyone will put some money in this project and outrival the now existing plants. But as long as the sun heats the waters of the oceans, the potential for power conversion though OTEC will always exist.

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David F. Mayer Dmayer@via-net.net Sea Solar Power Incorporated