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Electricity and the "Ataranai Oyster" - The Potential of Ocean Thermal Energy Conversion

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1. What is Ocean Thermal Energy Conversion?

With Japan's international pledge to become "carbon neutral" by 2050 by reducing CO2 emissions to virtually zero as a measure against climate change, "ocean thermal energy conversion" is gradually gaining attention as a renewable energy source that does not emit CO2 during power generation.

This power generation is still an unfamiliar technology, but as described below, it uses the temperature difference between warm surface seawater and cold deep ocean water to generate electricity[1]. Advantages of this technology include the fact that it does not require large-scale facilities, the fact that it is not affected by climate and thus can be expected to have a high operating rate whereas solar and wind power generation are affected by sunlight and wind and tend to have low operating rates, and the fact that the deep seawater that is pumped up during power generation is rich in nutrients and can be used for secondary purposes such as drinking water, cosmetics production, and primary industry.

Japan was the first country in the world to build a demonstration facility for ocean thermal energy conversion on Kumejima Island, Okinawa Prefecture, and began generating power in 2013. In August 2023, using its multifunctional properties, the company succeeded in cultivating "Ataranai oysters" in deep seawater, which does not harbor viruses or bacteria. Furthermore, in Pacific island countries and Indian Ocean island countries where the marine environment is similar to that of Kumejima, environmental surveys for the development of ocean thermal energy conversion have begun, with Japan's assistance.

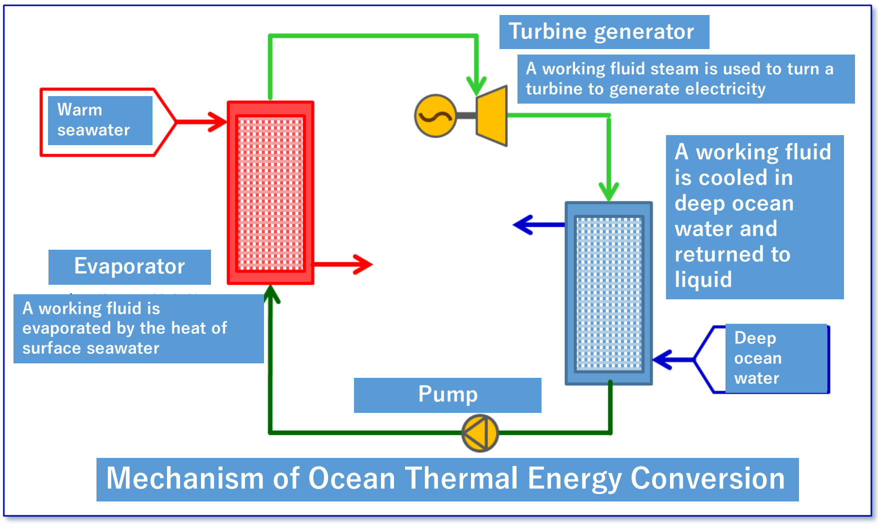
Currently, there are some issues to be overcome, such as the cost of power generation being relatively high compared to other power sources. However, as the use of offshore power becomes more widespread, the cost is likely to decline and a variety of marine applications are likely to develop both domestically and internationally.

This paper analyzes the multifunctionality and challenges of ocean thermal energy conversion, focusing on the demonstration on Kumejima Island, and discusses the future potential of this power generation.

2. Mechanism of Ocean Thermal Energy Conversion

The basic mechanism of ocean thermal energy conversion is similar to that of thermal and nuclear power generation. Steam is generated to rotate a turbine, and electricity is obtained from the friction. A working fluid with a low boiling point that changes from liquid to gas is circulated by a pump, as shown in Figure 1. Specifically, seawater at a depth of 600 to 1,000 meters, at a temperature of 5 to 7°C, is used as a cooling source to turn the working fluid into a liquid state, and warm seawater at a temperature of 25°to 30°C in the surface layer of the ocean is used as a warming source to turn the working fluid into a boiling state. The resulting large amount of steam is used to turn a turbine. After turning the turbine, the steam is sent to a condenser, where it is cooled by the deep seawater and returned to a liquid state. This cycle is repeated to generate electricity.

Fig. 1 How Ocean Thermal Energy Conversion Works



Source: Okinawa Ocean Thermal Energy Conversion Demonstration Facility webpage

Ammonia (NH_3), which is easily vaporized, is used as the working fluid. Ammonia has a low boiling point, is composed of nitrogen and hydrogen atoms, and emits no CO2. Therefore, as a substance that contributes to carbon neutrality, Japan is ahead of the world in ammonia utilization technology, and is promoting the practical application of mixed combustion, which reduces CO2 emissions by adding ammonia to coal-fired power generation, or power generation using ammonia as the exclusive fuel.[2]

Power can be generated if the annual average temperature difference between surface seawater and deep seawater is at least 20°C. In Japan, the Kuroshio Basin, which extends from Kyushu to Shikoku and Honshu, centering on Okinawa Prefecture and the Ogasawara

Islands, is an area suitable for this type of power generation, and not small by any means. Throughout the world, 100 countries and regions are expected to be able to introduce the technology, with potential power generation reaching 1 trillion kilowatt-hours (kWh).[3] This is more than 10 times Japan's annual electricity consumption in 2023 (90.9 billion kWh)[4].
The demonstration experiment on Kumejima Island started in 2013 with 100 kWh, and the goal is to reach 1,000 kWh by 2026, equivalent to about 15% of the island's annual power consumption, and 100,000 kWh by 2030 and beyond.[5]

3. Challenges and Potential of Ocean Thermal Energy Conversion

However, not all of the demonstration tests on Kumejima have been successful. Even if the plant moves to the 1,000 kWh class in 2026, it will still be only 1/1,000th the size of an average-sized nuclear reactor (1,000,000 kWh). Therefore, the cost of generating electricity from ocean thermal energy conversion, estimated based on the results of a five-year demonstration operation from FY2013 to FY2017, is 29.7 yen/kWh.[6] Compared to other power sources (see Table 1), along with offshore wind power, the high cost is obvious, indicating the disadvantage of using offshore power, which must be transmitted to land.

Table 1 : Power generation costs, operating rates, and operating years for each power source (2020)

power (button on TV, etc.)	coal	natural gas	nuclear power	offshore wind power	sunlight
Power generation cost (yen/kwh)	12.5	10.7	11.5	30.0	12.9
operating ratio	70% (of the total)	70% (of the total)	70% (of the total)	30	17.2% (in %)
Number of years in operation	40	40	40	25	25

Source: Prepared by the author with reference to the web page of the Agency for Natural Resources and Energy

On the other hand, based on the characteristics of ocean thermal energy conversion, it cannot be said to be relatively expensive. As mentioned at the beginning of this report, it does not cost an exorbitant amount of money for facilities, and it can generate power stably regardless of weather conditions. Furthermore, deep seawater used for power generation can be reused. Billions of yen in additional income is expected annually from aquaculture and fishing, the production of mineral salt, mineral water, and cosmetics. As a result, there will be room to further reduce electricity rates in the future. These are advantages that other renewable energy sources do not have.

As an example of reusing deep seawater, with oysters being cultivated on Kumejima Island using deep seawater and algae raised as feed, in August 2023 a complete land-based cultivation of "Ataranai oysters," free of norovirus and bacteria, was successfully completed.

Photo 1 Oysters: Success in Complete Land Cultivation of "Ataranai Oysters

Source: Courtesy of G.O. Farms, Inc.

Oysters take in and discharge approximately 400 liters of seawater per day, so if they are raised in surface seawater, viruses and bacteria contained in the seawater are also taken into the oyster's body. Although oysters are purified by exposing them to ultraviolet light and having them absorb clean seawater before shipping, it is said to be impossible to completely remove viruses and bacteria. Therefore, when eaten raw without heating, noroviruses and E. coli that bind to the oyster's digestive system can enter the human body and cause food poisoning. Deep seawater is free of viruses and bacteria, making it possible to cultivate "no-hit," or safe, oysters. The island's G.O. Farm, which is in charge of the aquaculture business, aims to commercialize the product in a few years.[7]

It is difficult to construct large thermal or nuclear power plants on islands, and transmitting power from a distance would be too costly. Given the above strengths, ocean thermal energy conversion technology originating in Japan could be widely used on remote islands in Japan and in island nations around the world. In fact, Japanese private companies and government-affiliated organizations have been increasing their activities in Japan and abroad in recent years. Mitsui O.S.K. Lines (MOL) is participating in a demonstration experiment on Kumejima Island and has begun a study on the commercialization of ocean thermal energy conversion in Mauritius in the Indian Ocean from 2022.[8] The Japan International Cooperation Agency (JICA) is also developing a study for the spread of ocean thermal energy conversion in the Republic of Palau and other Pacific island countries. [9]

4. Significance of OTEC Diffusion for Japan

Based on the characteristics of ocean thermal energy conversion and the progress that has been made to overcome the challenges, there are three possible implications for Japan in utilizing this technology.

The first is effective marine utilization. Japan has many remote islands, but if ocean thermal energy conversion becomes widespread, electricity can be supplied at a not-so-expensive price. Furthermore, the reuse of deep seawater could lead to regional development by creating aquaculture and other specialty products on each remote island and in coastal areas.

Second, it can be a means of strengthening relations with island nations in the Pacific and Indian Oceans. In the Indo-Pacific region, China is accelerating infrastructure development in island countries to expand its influence, and OTEC has the potential to be highly evaluated as a technology originating in Japan that takes advantage of the characteristics of each country and region.

Finally, it can complement Japan's current weakness in energy supply as source of power generation, utilizing technologies in which Japan has a comparative advantage. Japan is almost 100% dependent on imports of natural resources, and even in most renewable energy fields must rely on imports, as China holds a monopoly position in key components and rare earths , which are the raw materials. As a result, Japan is extremely vulnerable to restrictions or suspension of exports due to sudden changes in international conditions. If ocean thermal energy conversion, which consists of raw materials and technologies in which Japan is self-sufficient, can be used to supply a certain amount of electricity, this vulnerability can be alleviated to some extent.

The Seventh Basic Energy Plan, which serves as a guideline for energy policy and is revised every three years, is scheduled to be formulated within this fiscal year. It is hoped that the plan will include an objective evaluation of recent trends in ocean thermal energy conversion (OTEC) and a strategy for its future diffusion, taking into account the significance of the above-mentioned factors.

(End)

[1] How Ocean Thermal Energy Conversion Works," OTEC (Okinawa Thermal Energy Conversion Demonstration Facility) webpage. http://otecokinawa.com/jp/OTEC/index.html

[2] Agency for Natural Resources and Energy, "Ammonia as a 'Fuel'? (Part 1) - Familiar but Unknown Uses for Ammonia," January 15, 2021. https://www.enecho.meti.go.jp/about/special/johoteikyo/ammonia_01.html

[3] Cabinet Office, "Toward the Practical Application of Dream Power Generation and Ocean Thermal Energy Conversion," June 2023. https://www.gov-online.go.jp/eng/publicity/book/hlj/html/202306/202306_10_jp.html

[4] Enerdate, "Domestic Electricity Consumption," https://yearbook.enerdata.jp/electricity/electricity-domestic-consumption-data.html

[5] OTEC web page mentioned above.

[6] OTEC web page mentioned above.

[7] Author's interview with G.O. Farm, July 11, 2024.

[8] MOL Press Release, "MOL enters new phase to commercialize offshore thermal power generation in Mauritius," January 15, 2024. https://www.mol.co.jp/pr/2024/24005.html

[9] JICA press release, November 1, 2023. https://www.jica.go.jp/domestic/okinawa/information/press/2023/__icsFiles/afieldfile/2023/11/01/press.pdf