OCEAN THERMAL ENERGY CONVERSION

Abstract

A potential sustainable and renewable energy technology that generates energy using water bodies is Ocean thermal energy conversion. This report presents an overview of the OTEC process, its operating principles, types of this technology, and continuous sources of energy. This globe consists of more than 70% of oceans, which acts as a massive store of thermal energy that may be used to generate power. It creates power that has minimal effects on marine ecosystems and does so without releasing any direct greenhouse gases. Furthermore, it provides added advantages such as saltwater desalination and is rich in nutrients for deep-sea water upwelling, which may help marine ecosystems.

1. INTRODUCTION

Oceans cover 3/4th of the globe's surface, making them the world's most effective solar energy collectors. The ocean thermal energy conversion technique is one of the most sustainable renewable energy conversion technologies, converting solar radiation in the water body to electric energy. The rising need for environmentally friendly and renewable energy solutions has prompted the development of cutting-edge technology capable of harnessing the tremendous power of the Earth's seas. Ocean Thermal Energy Conversion (OTEC) emerges as an appealing solution, utilising temperature differences within the ocean to generate electrical power. In contrast to many traditional energy sources, OTEC provides regular and predictable power generation while minimising environmental impact.

The temperature of the ocean can be classified into two layers, where the solar radiation directly reaches the upper layer, which makes it the warm layer and the bottom of the ocean is cold layer. This conversion technique produces power through the benefit of the temperature differences between the ocean's warm surface(27°C) and the cold depths(5°C) [1]. The energy is generated by starting up a turbine.

Ocean Thermal Energy Conversion (OTEC) emerged to satisfy the emerging renewable and sustainable energy demand and reduce the demand for fossil fuels, Ocean Thermal Energy Conversion (OTEC) emerged. This technology generates power consistently and sustainably. OTEC was crafted explicitly with islands and remote coastal areas in mind, aiming to minimise environmental impact and offer the prospect of energy self-sufficiency.

Additionally, OTEC's capability to draw cold, nutrient-rich water from the ocean's depths opens avenues for applications such as desalination. Despite facing challenges, ongoing research and development endeavours strive to unlock the full potential of OTEC as a reliable and sustainable energy source.

These systems have the capacity to generate power with little harm to the environment. They can run constantly and emit no greenhouse gases, making them a steady and dependable source of energy. This technology makes the world a greener and more sustainable place for beings. New research and innovation in this technology will help to generate electricity without causing any trouble to the ecosystem

They are classified into three types: the Closed or Anderson OTEC Cycle Power Plant, The Open or Claude OTEC Cycle Power Plant and the Hybrid Cycle OTEC Power Plant.

1.1History

A French engineer, Jacques-Arsène d'Arsonval, proposed the concept of Ocean thermal energy conversion in the initial period of the 1800s, known as the closed-cycle system that employs ammonia, a secondary working fluid. Later, using water vapour as a working fluid, an open-cycle system was invented. In OTEC research, the United States rose to dominance in the 1960s and 1970s [2]. After a few years, other countries, such as Japan, India, etc are advancing in this technology, as shown in the Figure 1.

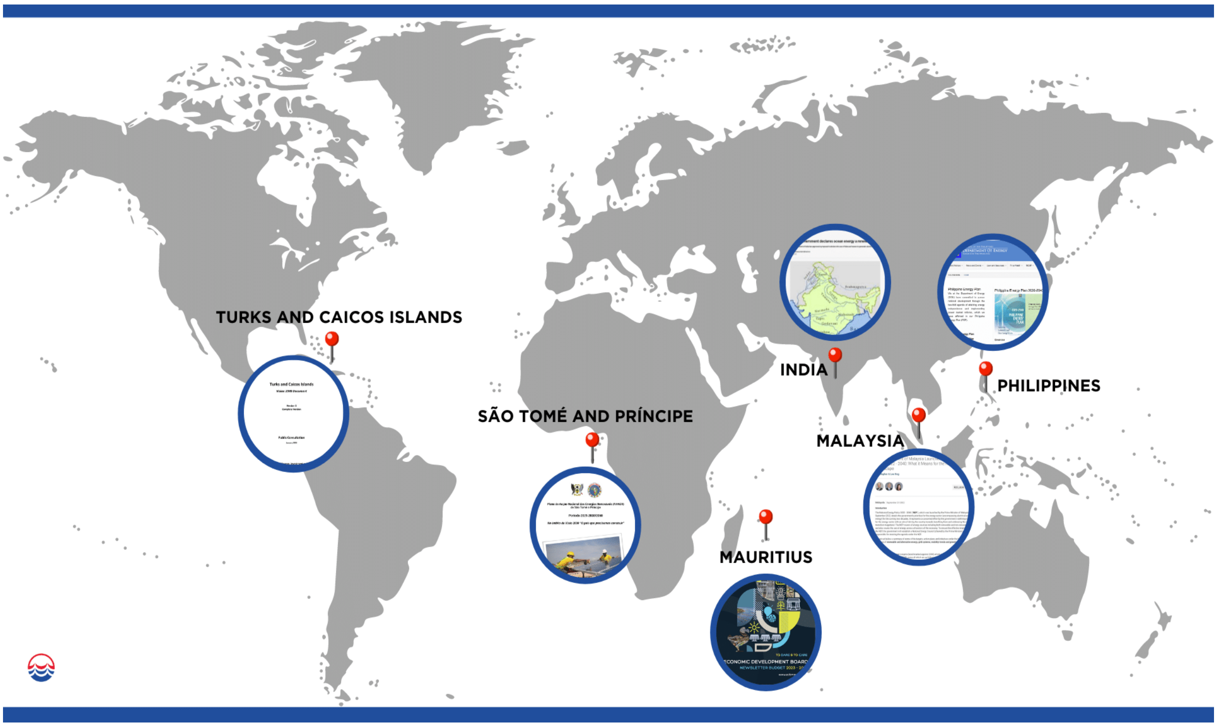

Figure 1 Countries with active policies of OTEC

1.2 working principle and process

The idea behind OTEC is to take advantage of the difference in the temperature that occurs in between the warmer tropical ocean surface water and more astonishing depths below.

The principle of the closed Rankine cycle plays a vital role in this energy conversion of solar radiation. Working fluids such as Ammonia and halocarbon refrigerant are evaporated using warm water, and electricity is produced when the fluid that is evaporated is coupled to a turbo alternator [1].

The OTEC process starts with the activation of pumps that pull warm surface water (28°C) and chilly deep water (5°C) from the ocean. The warmed water is then sent via a heat exchanger (evaporator), where it interacts with a working fluid, such as ammonia, causing it to evaporate by heat absorption. The resultant vaporised ammonia then expands, powering a turbine connected to an electric generator and, eventually, providing energy.

Following that, the turbine's expanding vapour actively propels the turbine, adding to the energy generating process. Condensation of turbine exhaust back into liquid ammonia is aided by exposure to cold deep water (5°C) in a separate heat exchanger. After that, the condensed ammonia is actively pumped back to the evaporator, ready to collect heat from the heated surface water and restart the cycle.

The OTEC plant's continuous sequence of vaporisation, expansion, and condensation of the working fluid enables it to successfully collect and convert the temperature difference between warm and cold layers of the waters into a sustainable and renewable source of power.

2. Closed loop OTEC cycle

The Closed-Loop (OTEC) cycle generates power by utilising the temperature difference between the warm upper-surface water and cool deep-sea water. Several essential processes are involved in this closed-loop system:

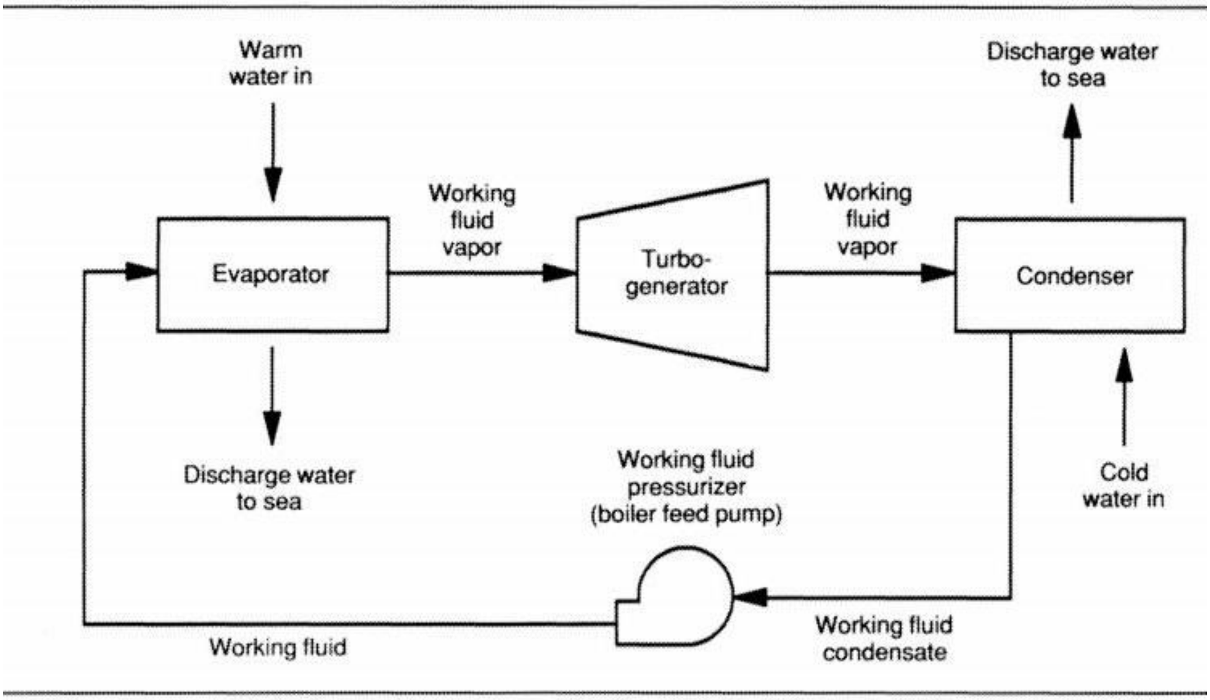

Figure 2 closed loop OTEC cycle

Warm Seawater Intake:
The procedure begins by pulling warm ocean surface water. The major heat source for the OTEC cycle is this water, which is normally approximately 28°C.

Evaporation of a Working Fluid:
Warm saltwater is pushed through a heat exchanger or evaporator, where it comes into contact with a working fluid, usually ammonia. The fluid absorbs heat from the water that is heated, vaporises, and becomes a high-pressure vapour.

Turbine operation:
Directing the vaporised working fluid to a turbine, where it expands and drives a generator, creating energy. This step transforms heat energy into mechanical energy effectively.

Energy Generation:
As the turbine spins, it creates energy that may be used for a variety of reasons, including as powering homes, factories, or other uses.

Condensation with Cold Seawater:
After crossing through the turbine, the exhaust vapour is directed to a condenser at a lower pressure. Cold deep-sea water, generally 5°C, is forced through the condenser, forcing the vapour to condense back into a liquid.

Working Fluid Pressurisation:
A pump pressurises the condensed working fluid before returning it to the evaporator, completing the closed loop. This guarantees that the OTEC system operates continuously and sustainably.[3]

The closed-loop OTEC cycle is self-sustaining and continuous, with the working fluid cycling through the phases of evaporation, expansion, and condensation again as shown in figure 2 . This closed-loop arrangement reduces environmental effects and eliminates greenhouse gas emissions, making it an ecologically friendly and sustainable energy alternative. While closed-loop OTEC systems are more ecologically friendly, they may encounter issues with heat exchanger performance and the selection of acceptable working fluids. Ongoing research and development aim to address these issues and optimise closed-loop OTEC for wider use as a sustainable energy source.

3.Open loop OTEC cycle

Warm surface water, normally maintained at around 28°C, is immediately collected from the ocean and channelled via a heat exchanger or evaporator during the operation of an open-loop Ocean Thermal Energy Conversion (OTEC) cycle.

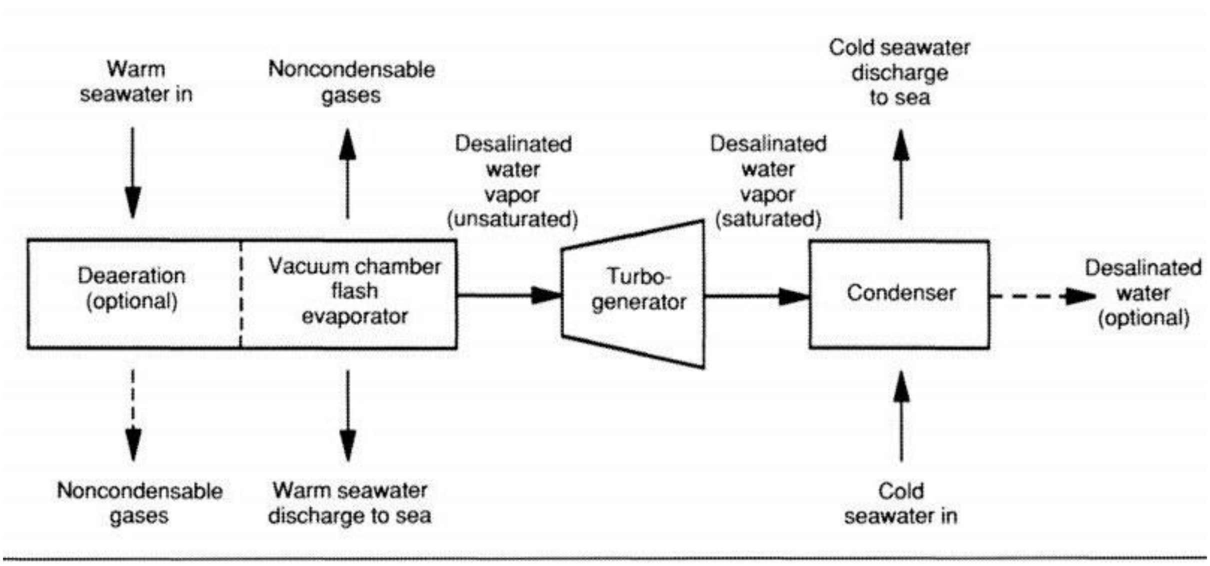

Figure 3 Open loop OTEC cycle

The temperature of the seawater causes the vaporisation of a working fluid, such as ammonia, held within the heat exchanger at this step. The resultant vaporised working fluid expands, moving a turbine connected to an electric generator, allowing thermal energy to be converted into electricity as shown in figure 3.

Following the creation of energy, the exhaust vapour is condensed back into liquid form using cold deep-sea water, typically registering at approximately 5°C, within a specialised condenser. In contrast to closed-loop systems, the condensed working fluid is then discharged into the deep ocean. This completes the open-loop cycle, which depends on the ocean's intrinsic temperature gradient to generate continuous and renewable power.

While open-loop OTEC systems provide benefits in terms of simplicity and efficiency, the possible environmental consequences of releasing warm saltwater into the deep ocean must be carefully considered.

4. Hybrid Cycle OTEC Power Plant.

The Hybrid OTEC cycle is a novel design that combines the components from both of the closed-loop and open-loop OTEC systems. Warm surface water, generally at 28°C, is taken from the ocean and used to vaporise a working fluid, such as ammonia, inside a closed-loop system in this hybrid model. The vaporised working fluid that results pushes a turbine attached to an electric generator, matching the closed-loop OTEC technology.

Following the creation of energy, the exhaust vapour is condensed into liquid form in a separate condenser using cold deep-sea water (about 5°C). The condensed working fluid is subsequently discharged into the deep ocean, mimicking the open-loop system as shown in figure 4 . The combination of these elements seeks to maximise the benefits of both closed-loop and open-loop OTEC systems, improving overall efficiency, flexibility to a variety of environmental conditions, and minimising environmental impact.[4]

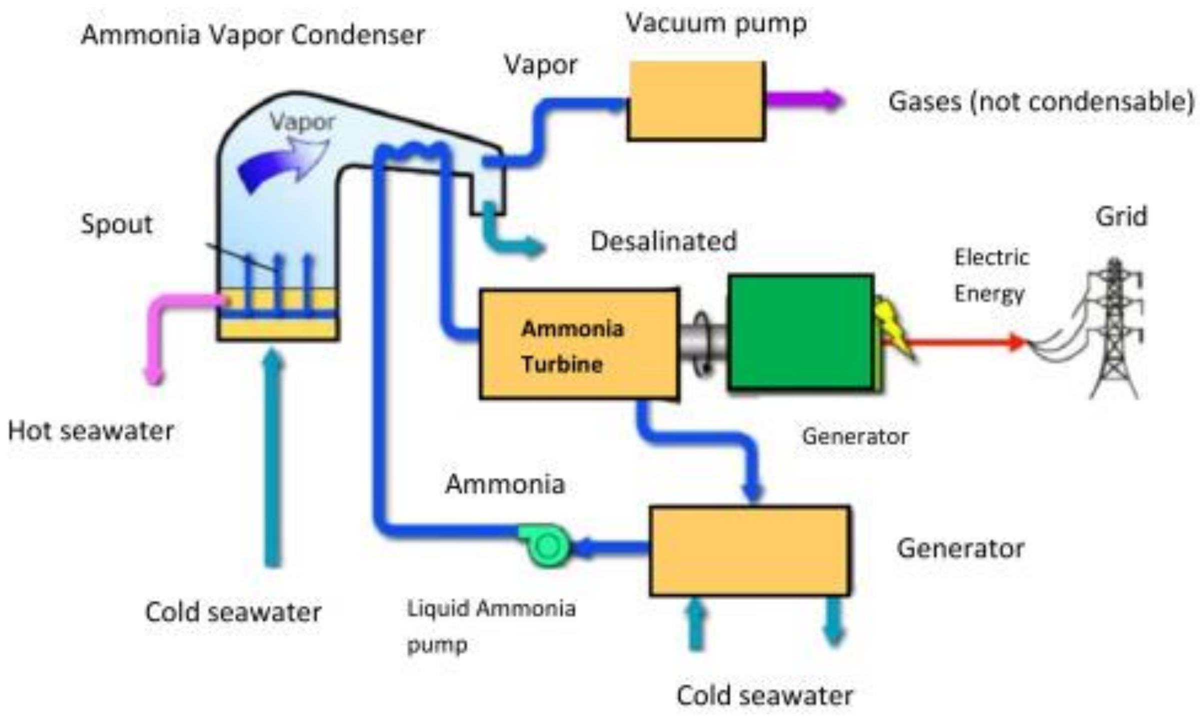

Figure 4 Hybrid OTEC

The Hybrid OTEC cycle shows promise as a versatile and efficient option for tapping into ocean thermal energy, hence contributing to the evolution of reliable and sustainable power production systems. Continuous research is required to optimise the integration of these components and ensure the viability of the Hybrid OTEC method on a larger scale.

5. Applications and environmental impact

5.1 Applications of OTEC

Power Generation: The primary use of Ocean Thermal Energy Conversion (OTEC) is in the generation of electricity. OTEC systems use the temperature difference between warm surface water and cold deep-sea water to create electricity, providing a sustainable and continuous energy option.[5]

Desalination: OTEC has the potential to be used in desalination techniques to produce fresh water from seawater. It is now feasible to evaporate and separate fresh water from saltwater using the warmth of surface water in a desalination plant, so helping to the relief of water scarcity concerns.[5]

Aquaculture and Mariculture: By delivering nutrient-rich deep-sea water, OTEC systems can help aquaculture and mariculture. The elevation of this water during the OTEC process can promote the growth of marine species, promoting sustainable seafood production practises.

Hydrogen generation: Through seawater electrolysis, OTEC has the ability to contribute to hydrogen generation. OTEC's energy may be used to split water into oxygen and hydrogen, providing a clean and sustainable source of hydrogen for a variety of uses.

Ocean Thermal Energy Conversion (OTEC) provides a stable and sustainable energy option for distant islands, reducing their dependency on imported fossil fuels. This has the ability to strengthen energy security and drive long-term development in remote areas.[6]

Climate Change Mitigation: By producing power without emitting greenhouse gases, OTEC actively helps to climate change mitigation. It is consistent with global efforts to transition towards purer and even more sustainable, reducing the carbon footprint associated with traditional power generation.

Air Conditioning and Refrigeration: By taking advantage of the temperature difference between warm surface water and chilly deep-sea water, OTEC technology provides a feasible choice for air conditioning and refrigeration, providing a sustainable and energy-efficient solution for cooling demands[7].

Tourism and Recreational Facilities: OTEC facilities, particularly those in tropical and subtropical zones, have the potential to serve as tourism and recreational centres. These platforms can offer unique experiences, instructional insights, and examples of sustainable energy activities.

Despite the numerous potential uses of OTEC, it is critical to recognise that widespread commercial deployment faces challenges related to optimising technology, significant initial costs, and the need for site-specific considerations. Continuous research and development are critical to overcoming these obstacles and realising the full breadth of OTEC's uses in a variety of scenarios.

5.2 Positive Environmental impact

Reduced Greenhouse Gas Emissions: OTEC systems create power without directly generating greenhouse gases such as carbon dioxide, assisting in climate change mitigation and lowering the carbon footprint associated with energy generation.

Limited Air and Water Pollution: Because OTEC does not burn fossil fuels, it produces minimal air pollution when in operation. Furthermore, closed-loop systems limit direct pollution release into the ocean.

Marine Resource Improvement: The OTEC process has the potential to improve marine habitats by bringing nutrient-rich deep-sea water to the surface. This nutrient-rich water may be used in aquaculture and mariculture, promoting long-term seafood production.

Utilisation of Renewable Resources: OTEC measures the temperature difference between warm surface water and cold deep-sea water, which are both renewable resources that are supplied naturally by solar energy and ocean currents.

5.3 Negative environmental impact

Changes in Local Ocean Temperature: The discharge of warm water into the ocean during the OTEC process has the potential to alter local ocean temperatures. This has the potential to have an influence on marine ecosystems around OTEC facilities and requires careful evaluation.

Impact on Marine Life: Water intake and outflow during OTEC operations can have an impact on marine life, particularly smaller species and larvae. To mitigate these consequences, thoughtful design and careful site selection are required.

Noise and Vibration: The operation of turbines and pumps in OTEC systems may cause noise and vibrations, which may have an influence on marine life in the area. Mitigation measures, such as acoustic barriers, may need to be put in place.

Impact of Infrastructure Installation: The building and deployment of OTEC infrastructure, like as pipelines and platforms, has the potential to disturb local ecosystems. Thorough planning and environmental impact evaluations are required to reduce these disruptions.

Material Use and trash: Materials are used in the development and deployment of OTEC systems, and the decommissioning of old systems might result in trash. Responsible material consumption and recycling strategies must be addressed[8].

In conclusion, while OTEC provides several environmental advantages, a full examination and effective control of possible negative consequences are critical. Sustainable site selection, thorough system design, and ongoing environmental research are critical to ensuring that OTEC plays a constructive part in the transition to cleaner and more sustainable energy sources.

6. Conclusion

In conclusion, Ocean Thermal Energy Conversion (OTEC) appears as a promising and innovative technology with tremendous potential for contributing to the global search for clean and renewable energy sources. OTEC delivers a constant and stable power supply by using the persistent temperature disparity between warm surface water and chilly deep-sea water. OTEC's environmental benefits, which include low greenhouse gas emissions and the potential for increased marine resource utilisation, position it as a greener option to many traditional energy sources. Despite obstacles like as high initial capital expenditures, site-specific considerations, and potential environmental implications, continuous research and technology advancements are aimed at optimising OTEC systems for greater integration.

OTEC's adaptability, as seen by applications ranging from power production to desalination and aquaculture, demonstrates its ability to handle a world broad concerns, including energy security and climate change mitigation. As the globe moves towards more sustainable energy solutions, OTEC stands out as a source of hope for a cleaner, greener, and more resilient energy future.

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