

OTEC Potential of East Nusa Tenggara Province in Indonesia

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Abstract. Indonesia is the largest archipelago country in the world, located between Indian Ocean and Pacific Ocean. Indonesia has more than 17000 islands with 70 per cent of the region is ocean. The Growth of the economic and population in Indonesia increasing the demand of the electricity annually, in 2015 alone electricity consumption in Indonesia reaching 200 TWh and will continue increasing every year. However, East Nusa Tenggara Province electrification ratio only around 58.64%, this is the second lowest ratio in Indonesia. This electrification ratio describes the level of availability of electrical energy for the community. Power Plant with renewable source placement in East Nusa Tenggara Province or smaller district need to be prioritise to cope with the low electrification ratio. Renewable sources for power plant have a good potential to work with, in example wind power, solar power, geothermal, or biomass. In addition, another renewable source that not yet known is from the ocean itself. Ocean Thermal Energy Conversion (OTEC) is one of the renewable source method from ocean. This paper will uncover the potential of OTEC in East Nusa Tenggara province so it will bring possibility to build an OTEC power plant in the future.

1. Introduction

Astronomically, Indonesia is located between 6° 04' 30" North latitude and 11° 00' 36" South latitude, and between 94° 54' 21" and 141° 01' 10" East longitude and lies on equator line located at 0° latitude line. In terms of geographic location, Indonesia is located between Asian Continent and Australian Continent, and between Indian Ocean and Pacific Ocean. As an archipelago country, Indonesia consist of thousands of islands interconnected by strait and seas. Indonesia has 34 provinces spreading over five main islands and four archipelagoes. Each province has its own legislature and governor which are subdivided into regencies and cities and then further subdivided into districts and again into administrative villages [1].

East Nusa Tenggara (NTT) is one of the province in Indonesia. Land area of NTT is $\pm 47,931.54$ km² or 2.49% of Indonesia's land area and water area $\pm 200,000$ km² outside the water of Indonesian Exclusive Economic Zone (ZEEI). NTT Province consists of 21 districts and 1 city, which is spread on three large islands and some small islands, among others: Timor Island (Kupang City, Kupang District, South Central Timor, North Central Timor, Belu and Malacca), Sumba Island (East Sumba, Central Sumba, West Sumba and Southwest Sumba), Flores (West Manggarai, East Manggarai, Ngada, Nagekeo, Ende, Sikka and East Flores); Small Islands (Alor, Lembata, Rote Ndao, and Sabu Raijua). The foremost islands in NTT are disadvantaged areas due to their remote and isolated locations that are less touched by development.



Likewise, the electrical conditions in the province of NTT, there has been no distribution of electricity development in all NTT areas [2]. Based on Statistik Ketenagalistrikan 2015, electrification ratio of NTT is 58,64% [3]. That is the second lowest in Indonesia. This electrification ratio describes the level of availability of electrical energy for the community. The total of PLN electricity users in NTT are 628,427 customers, with the largest percentage in Kota Kupang of 102,743 customers. Meanwhile, the lowest PLN electricity users are in the regencies of West Sumba and Central Sumba with 13,143 customers. The only solution to those problems is a good diversification of power resource on both its variety and amount through alternative power resource, especially the renewable one. Ocean Thermal Energy Conversion (OTEC) is one of the renewable source method from ocean.

2. Ocean Thermal Energy Conversion

2.1. OTEC System

OTEC is a technology of electric power generation that utilizes the temperature difference between water at sea level and deeper seawater. OTEC uses heat energy stored in warmer sea levels to produce steam from ammonia fluid to rotate steam turbine. Meanwhile cold water from within the ocean is pumped to the surface to cool down steam out from turbine.

Temperature difference between the sea surface and deep sea, with depth not more than 1000m (3280 ft), is around 20 degrees Celsius, or about 68 degrees Fahrenheit. The greater the temperature difference will generate bigger electricity as well [4]. OTEC system uses circulate fluids in cycle and with help of heat exchanger, the heat from the surface water of the will be absorbed by fluids which then will evaporate it. The steam generated will turn the turbine that coupled mechanically with electricity generator. The steam the exits from the turbine will be condensed with seawater taken from deep-sea level, so it will complete the operation cycle. The diagram of the system can be seen below.

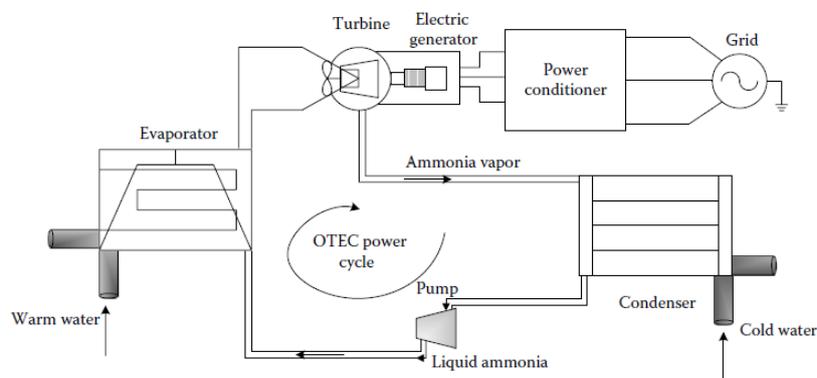


Figure 1. OTEC system [5]

OTES system can be applied offshore or onshore near the beach. Offshore OTEC usually uses cold seawater taken from depth around 600 – 1000m below sea level, and warm water taken from sea level up to 30m below. Offshore OTEC is a floating construction which anchored to the seabed, this construction could be a lighthouse or a buoy. Underwater cable use to transmit electricity generated to the main building on the shore. Onshore OTEC system needs longer pipe for the seawater intake because of the distance between the construction and the sea. However, onshore OTEC system have the benefits because the system will discharge a desalination water that can be used for other purposes.

2.2. Classification of OTECs

2.2.1 Closed-Cycle OTEC Systems. A closed-cycle OTEC systems uses low boiling-point fluids like ammonia, that later will be boiled until changed into steam. This steam will turn the turbines that coupled with turbo-generator. Warm seawater pumped through the heat exchanger which where the

boiling happens, the second heat-exchanger served as the cooler, with cold deep seawater serve as a cooler. The steam then will be reverted back to fluids through condensation process, and the cycle continues. Figure 2 shows closed-cycle OTEC systems.

2.2.2 Open-Cycle OTEC systems. In the Open-Cycle OTEC system, uses seawater as the main components (figure 2b). The boiling-point of water can be changed by changing the pressure around it. In this system warm seawater pumped into a vacuum chamber with low pressure around 2% that lowers the seawater boiling point. The seawater then will be boiled and change into steam that will turn the low-pressure turbine. The steam and then will be cooled down with cold deep seawater. The result of this process is desalination water that can be used as irrigation and/or other purposes. This system benefits for the area that have rare access to clean water.

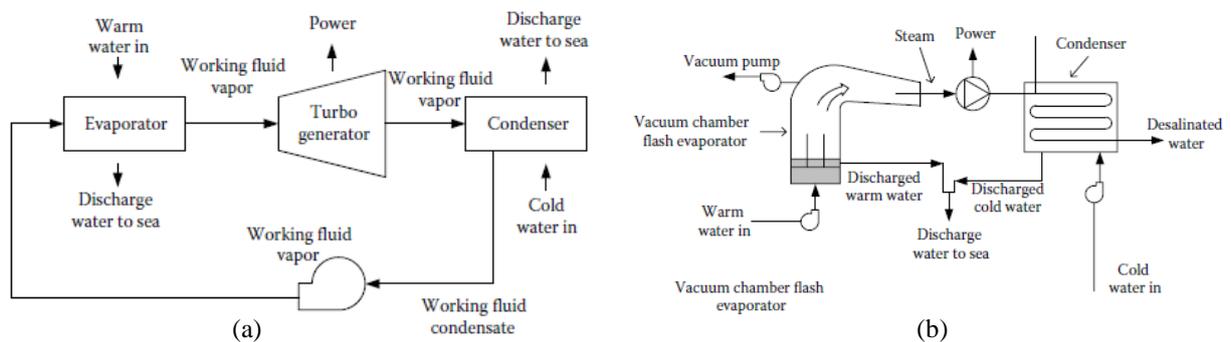


Figure 2. Operational system diagram of OTEC: (a) close cycle (b) open cycle

2.2.3 Hybrid Cycle OTEC systems. This system called hybrid cycle because it combines both from open-cycle and closed-cycle method. In this system both ammonia and warm seawater servers as the main components. The warm seawater will be divided into 2 purposes, first one used as evaporator for the ammonia and the second one will be evaporated just like the ammonia. Each steam (seawater and ammonia) will be separated and turns the turbine just like closed cycle for ammonia and open cycle for seawater. Then, ammonia will be condensed and reuse as main components, but seawater will be distilled and discharged for other purposes.

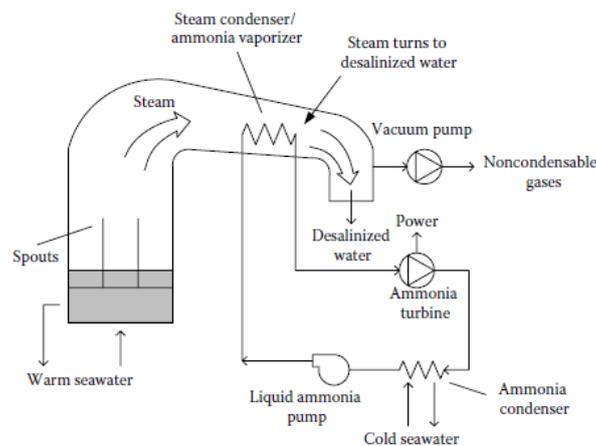


Figure 3. Hybrid Cycle OTEC systems

2.3. Thermodynamic Efficiency

According to the thermodynamics first law, the energy balance for the fluid served as the main component is stated by:

$$W = Q_H - Q_C \quad (1)$$

Where Q_H is the value of the heat energy absorbed from the heat reservoir and Q_C is the value of the heat energy absorbed from the cold reservoir, which has negative value. According to the thermodynamics second law, the system efficiency restricted by the Carnot efficiency cycle. The maximum possible efficiency would be

$$\eta = \frac{W}{Q_H} = \frac{Q_H - Q_C}{Q_H} = \frac{T_H - T_C}{T_H} = 1 - \frac{T_C}{T_H} \quad (2)$$

Equation 2 define the principal from Carnot's efficiency. Based on this equation, can be said that maximum efficiency from the heated engine depends on both hot and cold reservoir. Because of this, the seawater temperature may affect the power generated by OTEC system, in addition temperature of the seawater are varied throughout the year.

3. Potential OTEC in East Nusa Tenggara (NTT)

OTEC is one of the renewable resource system that can be used in Nusa Tenggara Timur (NTT). There are 2 suburbs and one city that can OTEC system could be applied, which is Waingapu, Ende and Kupang respectively. These three locations have a high potential because of several reasons. The First one is because the location is near the sea. The second is because the seawater temperature near these location is relatively stable throughout the year. The last one is because the distance from the deep seawater intake is not far. Figure 5 show the distance between shore and the minimum depth (1000m) for deep seawater intake, while table 1 show the average temperature for the seawater on the surface and the temperature at 1000m depth. Figure 6 taken from Ocean Data View [6], show yearly temperature from different depth from three different location, Waingapu, Ende, and Kupang respectively.

Table 1. Annual surface and seabed (1000 m) temperatures on several location in NTT.

Location	T_{\max} (°C)	T_{\min} (°C)	Efisiensi (η)
Waingapu	27,97	4,88	0,826
Ende	27,76	4,87	0,825
Kupang	28,06	4,63	0,835



Figure 4. Distance between shore and the minimum depth at Waingapu and Ende

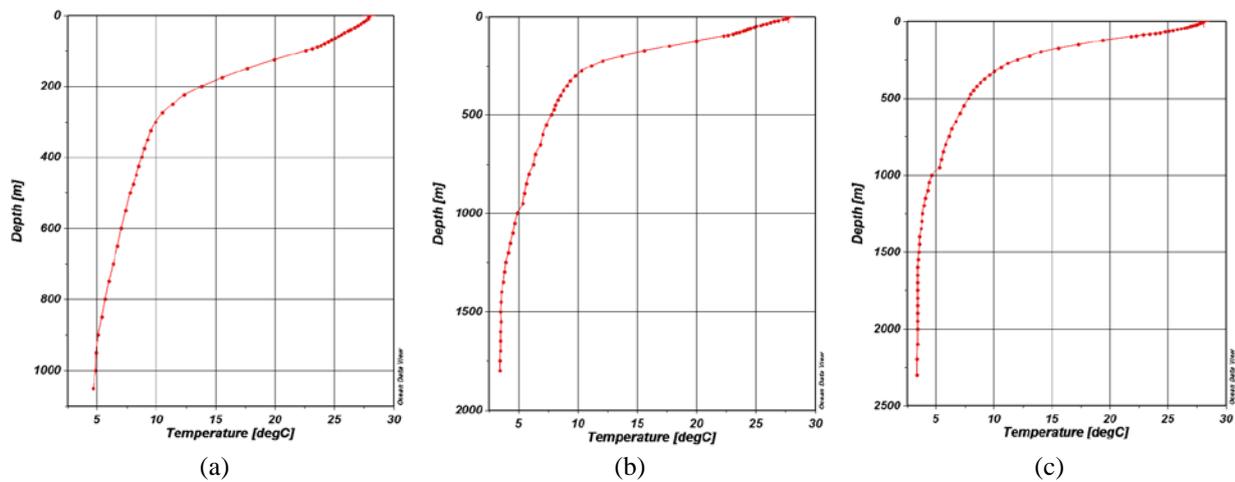


Figure 5. Profil temperature at different water depths in (a) Waingapu (b) Ende dan (c) Kupang

4. Conclusion

This journal discussed OTEC potential in three different location in NTT, Waingapu, Ende and Kupang. From this journal can be concluded that if applied, OTEC system in Waingapu have an efficiency of 0,826, and OTEC system in Ende have 0,825 efficiency, lastly in OTEC system in Kupang will have efficiency of 0,825. OTEC system have a large potential in Indonesia because of its sea temperature is ideal for OTEC system. These results are expected to help optimize the use of OTEC in Indonesia in the future.

Reference

- [1] Badan Pusat Statistik 2016 *Statistical Yearbook of Indonesia 2015*. BPS Statistic Indonesia
- [2] Seri Analisis Pembangunan Wilayah Provinsi Nusa Tenggara Timur 2015
- [3] Agoes Triboesono 2016 *Statistik Ketenagalistrikan 2015* Kementerian Energi dan Sumber Daya Mineral
- [4] Khaligh A and Onar C 2010 *Energy, Power Electronics and Machines Series*CRC Press Taylor & Francis Group
- [5] Koto J 2016 *Potential of Ocean Thermal Energy Conversion in Indonesia* Vol.4 No.1 International Journal of Environmental Research & Clean Energy
- [6] World Ocean Atlas 2013 [Cited 13 September 2017] <http://odv.awi.de/en/data/ocean/world-ocean-atlas-2013/>
- [7] Syamsudin M L and friend 2015 *OTEC Potential in The Indonesian Seas* Energy Procedia 65 (2015) 215 – 222 Conference and Exhibition Indonesia – New, Renewable Energy and Energy Conservation
- [8] Avery W H and Wu C 1994 *Renewable Energy from the Ocean : A Guide to OTEC* Oxford University Press
- [9] Sinuhaji A R 2013 *Potential Ocean Thermal Energy Conversion (OTEC) in Bali* Vol. 1 (2015) 5-12 Renewable Energy and Energy Conversion Conference and Exhibition