Initial Study Of Potency Thermal Energy Using OTEC (Ocean Thermal Energy Conversion) As A Renewable Energy For Halmahera Indonesia

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Abstract. The Blue Energy is the one of renewable energy. Indonesia as a maritime country has many potential to implement this Blue energy, but it still an advance technology to convert this energy into the electricity. The concept of OTEC with Land Based System is to boost the cost effectiveness of ocean technology. OTEC Land based system which is integrated with the cooling system, water desalination systems, aquaculture, and agriculture. Geographically Halmahera district is located in the Eastern Province of North Maluku. Halmahera is the one of remote island in Indonesia that still lack of electricity. By processing the Argo Float data in 2013-2015 using ODV (Ocean Data View) software, shows the difference of ocean temperature in Halmahera sea surface the range is 29°C. In depth of 1000 m, the sea temperature ranging from 2°C. The Electrical potential of OTEC a long 55 km Halmahera beach are around 93,1% as potential source of OTEC technology. The electricity OTEC prediction is 5,12 MW. Capacity factor of OTEC is 0.857, means that Halmahera have electrical potential for applying OTEC for each year is 35,88 GWh/year.

Keyword: OTEC, Renewable Energy, Thermal energy, Blue Energy, Halmahera

1. Introduction
The demand of energy in Indonesia is increase each year. The distribution of electricity in Indonesia is still worst. There are many of renewable energy that can be applied in Indonesia to solve this problem. Since Indonesia is a vast archipelago country (> 18,000 islands), The Blue Energy technologies should play an important role in the future. The potential of The Blue Energy ratified by ASELI version (Association Energy of Indonesian Seas ) in 2011; the potential of tidal current theoretically is 160 GW but technically 22,5 GW, and the potential practical 4,8 GW; the tide has the potential theoretical 510 GW, technical potentially is 1,2 GW, the potential practical 1,2 GW, and the latter is the sea temperature have the potential theoretically is 57 GW, technical potential is 52 GW, and the potential practical is 43 GW [1]. From this data indicate that ocean thermal energy temperature is suitable to be implemented in the tropical areas such as Indonesia, but it still need an advanced technology to convert the ocean thermal energy into the electrical energy.

OTEC (Ocean Thermal Energy Conversion) in Indonesia have not been developed in the laboratory or in the field. Whereas OTEC technology itself has a variety of useful byproduct such as water
desalination, hydrogen, lithium, ice sea water, greenhouse crops, and cultivation. Today, the Association Energy of Indonesian Seas (ASELI) still promote the implementation of OTEC technology through the cooperation with the government of Japan and Indonesia [2].

Halmahera is a remote island in Indonesia that is potential to built OTEC technology. By processing the Argo Float data using ODV (Ocean Data View) software, shows the difference of ocean temperature in Halmahera sea surface range is 24°C to 29°C. In depth of 1000 m, the sea temperature ranging from 2°C to 3°C. From these data indicate that the area in Halmahera has the potential to set up power plants using OTEC, so it can raise the government sector in Maluku Islands [3]. The aim of this research is initial study of OTEC potention in Halmahera area, and do the feasibility study of OTEC in Halamahera area.

2. Methodology

Indonesia as an archipelago island has a vast area of ocean and Indonesia is a tropical island that is make indonesia has big potention on thermal energy. Research and analysys is needed to establsh the idea of renewable energy from themal energy by using OTEC (Ocean Thermal Energy Conversion) technology.

2.1. Literature Study

2.1.1. Halmahera. Geographically Halmahera district is located in the Eastern Province of North Maluku. East Halmahera located at 1° 4′ - 0° 40′ LS and 126° 45′ 130° 30′ east longitude. Halmahera is the one of remote island in Indonesia that still lack of electricity, because the electric will be turn off at 6.00- 18.00 WITA [4 -5]. The need for electricity in the province of North Maluku supplied by several isolated systems. such as Systems Ternate, Soa Siu, the Vedas, Bacan, Dofa, Jailolo, Sanana, Tobelo, Subaim, Maba-Buli, Patani, and Sofifi. From 12 systems that supply electricity in the province of North Maluku, 4 system (System Soa Siu, the Vedas, the Maba-Buli, and Patani) are in a state of "Surplus", and eight other system (System Ternate, Bacan, Dofa, Jailolo, Sanana Tobelo, Subaim, and Sofifi) are in a state of "deficit". The electrification ratio in North Maluku province reached 49.44% and the ratio of electrified villages amounted to 93.06%. The waiting list has reached 2,812 PLN or demand of 7.1 MVA [10].

Figure 1. Electricity system in North Maluku Province.
Table 1. The Balance of power system in Maluku and North Maluku 2010-2014

| Requirement       | 2010 | 2011 | 2012 | 2013 | 2014 |
|-------------------|------|------|------|------|------|
| Household         | GWH  | 327  | 360  | 393  | 427  | 462  |
| Comersial         | GWH  | 83   | 87   | 90   | 93   | 97   |
| Public            | GWH  | 71   | 76   | 81   | 87   | 94   |
| Industry          | GWH  | 7    | 8    | 8    | 9    | 10   |
| Total Requirement | GWH  | 489  | 530  | 572  | 616  | 663  |
| Growth            | %    | 7.5  | 8.4  | 8.0  | 7.7  | 7.5  |
| Decrease & loses  | %    | 7.8  | 7.7  | 7.6  | 7.5  | 7.5  |
| Decrease own use  | %    | 2.0  | 2.0  | 2.0  | 2.0  | 2.0  |
| Total decrease & Loses | % | 9.8  | 9.7  | 9.6  | 9.5  | 9.5  |
| Peak load         | MW   | 108  | 116  | 126  | 135  | 145  |
| Installed power   | MW   | 43   | 106  | 123  | 128  | 204  |
| Additional power  | MW   | 64   | 20   | 9    | 80   | 47   |
| Backup power      | MW   | 42   | 10   | 6    | 73   | 106  |

The table 1 shows the distribution of fuel to North Maluku province served by Pertamina UPMS VIII Jayapura [10]. Pertamina UPMS VIII serve the supply and distribution of fuel that includes four provinces. There are the province of Papua, West Papua, Maluku and North Maluku [10]. There are some obstacles encountered in the provision of fuel in this region. These constraints, such as geographical position is an archipelago with many areas still remote (remote areas). These condition makes Halmahera lack of electricity.

2.1.2. OTEC. The operating system of OTEC seems like a steam engine, with evaporation and condensation [3-4]. Differences pressure caused turbine spun to generate electricity. OTEC technology can be used one of the hybrid system cycle. Hybrid system advantage are open and closed cycles. Hybrid cycles used seawater laid low pressure in the tank (vacuum chamber) to give steam. Steam are used to vaporize fluid low dotted boiling (ammonia or another) will move turbine to generate electricity. Sea water vapor and condensed to produce freshwater desalination. Using ammonia anhydrous as a working fluid, modeled with Rankine cycle saturated the principle of OTEC. Mechanism working will be explained by figure 2 [5].

2.2. Collecting Data and Data Processing

Data that will be use is origin from Argo Float Data (2013-2015). Argo Float is array global more than 3,000 who have a profile for measuring temperature and salinity at 2,000 m altitude from the sea. This allows for the first time, monitoring continuous of the temperature, salinity, and the velocity from the upper sea. The data delivered and available for public in hours after collection. The data can be download from www.argodatamgt.org. Data processed by ODV (Ocean Data View). The difference temperature of Halmahera ocean and can be displayed in diagram that can easily to understand [5].
2.3. Data Analysis

Data analysis from literature study and processing Argo Float data with ODV should be analysed[7]. The analysis that will do in this initial study are analysis of potential area, efficiency of the technology, electrical analysis, and the pay back period. This analysis aimed to explore all opportunities, advantage, and loss of OTEC potential in Halmahera. There are many theoretical equation and term that are used to do this analysis, such as:

2.3.1. Analysis maximum efficiency of an OTEC system

There is a theoretical limit, up to a maximum efficiency of an OTEC system by converting heat stored in the warm surface water of tropical oceans into mechanical work[11].

\[ \eta_{\text{max}} = \frac{(T_w - T_c)}{T_w} \]

where:
\( \eta_{\text{max}} \): maximum efficiency
\( T_w \): absolute temperature from warm water
\( T_c \): absolute temperature from cold water

2.3.2. Analysis Payback Period

Adopting a formula based on zero net present value is given by: [8] :

\[ X = \frac{d-i}{A} \] (2)

Equation 1 explain how to get result of \( X \).

\[ Y = (1-CC).X \] (3)

Input equation 1 to equation 2 so we can produce result of \( Y \)

\[ O = \frac{(1 + i)}{(1 + d)} \] (4)

After that arithmetic equation 3 to get result of \( O \)

\[ N = \text{Log} \left\{ \frac{Y}{Y \text{ Log O [year]}} \right\} \] (5)

Finally input equation 2 and equation 3 to equation 4 to get result of pay back period of OTEC.
Where:
CC : Estimated costs
A : Income and expenses per year
N : Payback Period
d : Discount Rate
i : Inflation

3. Result and Discussion

3.1. Analysis of Potential Source in Halamahera

The location of a commercial OTEC plant has to be in an environment that is stable enough for an efficient system operation. The aim of these analysis is to know the potential place for developing OTEC in Halmahera. By processing the Argo Float data using ODV (Ocean Data View) software, shows the difference of ocean temperature in Halmahera sea surface range is 24° to 29°C. In depth of 1000 m, the sea temperature ranging from 2° to 3°C. The relation of depth and temperature shows in the figure 3 that has been processing using ODV software and MS.Excel.

![Temperature vs Depth](image)

**Figure 3** Large-scale distribution of resources OTEC thermal Halmahera

After processing data with ODV (Ocean Data View) it shows in figure 5 that the longitude and latitude affect the distribution of surface temperature. The range of temperature shows with the gradient of the colour. The figure 4 shows that the North Halmahera especially Akelamo is a potential place to built the OTEC, because the difference temperature in this area is very significant.

![Large scale distribution of OTEC thermal resource of Halmahera](image)

**Figure 4.** Large scale distribution of OTEC thermal resource of Halmahera

3.2. Analysis The Efficiency of OTEC in Halmahera

This analysis is the result of the calculation by using maximum efficiency of an OTEC system equation [term 2-5] in the methodology.
The result of the efficiency is adequate, so the north sea of Halmahera is the most potential in the development of sea surface water temperatures for OTEC. If it take 100 KW for input power and carnot efficiency 93,10344, so the estimation result of the net power become 93,103 KW.

### 3.3. Analysis of Electrical Potential

Electrical potential of OTEC technology a long 55 km Halmahera beach, around 95 % as potential source of OTEC at more than a 1000 m depth. The long of coastline is 55 km. The Source of OTEC potential is 93,1 %: 0.931 x 55 km = 51.2 km. The distance between 100 MW OTEC is 10 km, means that potential power for each kilometer is \( \{100/10\}\) MW. Capacity factor of OTEC is 0.8 [5,12]. The assumed of Electrical Potential represented in table 2.

### Table 2. Assumption for the calculation electrical potential

| No | Variabel                      | Value  | Unit   |
|----|-------------------------------|--------|--------|
| 1  | Energy Source                 | 51,2   | Km     |
| 2  | OTEC Energy Potential         | 98,304 | MWh/day|
| 3  | Total Generator               | 10     | /km    |
| 4  | Efficiency                    | 93,1   | %      |
| 5  | Depth                         | 1000   | Meter  |
| 6  | Power capacity for each generator | 20 | KWh   |
| 7  | OTEC electrical potential     | 35,88  | GWh/year|

### 3.4. Analysis of Pay Back Period

The assumed value used to estimate the cost of payback time N for a 5250 KW OTEC plant, which may represent targeted the limit of OTEC. Based on equation number 4 from on estimation cost by L. A. Vega, Ph.D. of Pacific International Center for High Technology Research (PICHTR), Honolulu, Hawaii Capital Investment [7-9]. The result of assumption represented in table 2, with revenue from electricity sales at the end of the first year of the project. With CF (capacity factor) 80% and electricity price US$ 10/kWh, A = US$ 3,675,000. , favourable compares with the projected life OTEC plan, typically 20 – 30 years.
Table 3. Assumption for the calculation of the payback period

| No | Variabel | Value   | Unit  |
|----|----------|---------|-------|
| 1  | N        | 11      | Year  |
| 2  | A        | 3.675.000 | US $ / kW |
| 3  | CC       | 7.000   | US $ / kW |
| 4  | D        | 20      | %     |
| 5  | I        | 10      | %     |

3.5. Future Plan of OTEC in Halmahera

In this project the OTEC system with Land-based system. The Land-based system do not require a sophisticated mooring system, lengthy power cables and more extensive maintenance as required with open ocean environment. Land-based system is more easier and cheapest than using the off-shore. In addition, for the future plan the land-based sites allow OTEC to be associated with industries such as agriculture and those needing cooling and desalinated water [Fig.5]. Below is desaign for future plan of OTEC in halmahera:

![Figure 5. Layout design OTEC in Halmahera](image)

Figure 5. shows the OTEC that will be implemented in Halamahera not only for generate the electricity, but it associated with the water desalination, temperate zone agriculture, aquaculture and fish pond to encourage the local prosperity economically.

![Figure 6. Design of OTEC in Halmahera from the ocean side](image)
Those upon figure are shows the future [Fig.5, Fig.6, and Fig.7] design of OTEC plant, which is using Land-base system concept. OTEC has some benefit, such as:

- Helps produce fuels such as hydrogen, and lithium
- Produces base load electrical energy.
- Produces desalinated water for industrial, agricultural, and residential uses.
- As a resource for on-shore and near-shore marine culture operations.
- Provides air-conditioning for buildings.
- Provides moderate-temperature refrigeration.
- Has significant potential to provide clean, cost-effective electricity for the future.

4. CONCLUSION

OTEC by using the concept of land based system which is integrated with the cooling system, water desalination systems, aquaculture, and agriculture. By using the Land-base system is more cheaper, safer and easier than using the Off-shore system. This renewable energy can produce not only the electricity energy, but also for agriculture, and fisheries to develop the remote island in Indonesia such as Halmahera. Halmahera is a remote island in Indonesia that is potential to built OTEC technology. By processing the Argo Float data using ODV (Ocean Data View) software, shows the difference of ocean temperature in Halmahera sea surface range is 29°C. In depth of 1000 m, the sea temperature ranging from 2°C. The Electrical potential of OTEC along 55 km Halmahera beach are around 93.1% as potential source of OTEC technology. The electricity OTEC prediction is 5.12 MW. Capacity factor of OTEC is 0.857, means that Halmahera have electrical potential for applying OTEC for each year is 35.88 GWh/year. More comprehensive research and study are needed to know the possibility location for OTEC to built and estimated cost.

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