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OTEC Strengthens and Sustains Indonesia's National Economic and Defense at 3T (Frontiers, Remotest & Outermost) Regions
-Case Study: 2 MW Pilot Plan at Siberut, Sumatra Barat, Indonesia-

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ABSTRACT

Indonesia is an equatorial country located at latitudes less than 20 degrees which is covered by 77 % ocean with thousand islands, strain and many difference of topography. Most of the islands are located closed by deep sea and the frontiers, remotest & outermost (3T) regions. Availability of fresh water, electricity, food, employment, education, defenses are still a critical and urgent issues in the 3T regions and must be addressed by the government. OTEC releases a large amount of warm sea water for evaporating and cold sea water for condensing ammonia to rotate the turbine. The discharge warm and cold sea water are potentially use for fisheries, agriculture, resort and hotel for tourism industries. This paper discussed on potential of OTEC for strengthening and sustaining Indonesia's National Economic and Defense at 3T (Frontiers, Remotest & Outermost) regions. As a case study 2 MW Pilot Plan at Siberut, Sumatra Barat, Indonesia. Beside generating electricity, It was founded that the 2MW OTEC has great benefits to proves drinking fresh water, opened opportunity for Fishery Industry and agriculture Industry, Equitable infrastructure development, development tourism Industry and strengthening Politic & Defense.

KEY WORDS: *Siberut Island, Sumatera Barat, Indonesia, Ocean Thermal Conversion Energy, Frontiers, Remotest & Outermost Regions.*

NOMENCLATURE

BAPPENAS	Badan Perencanaan Pembangunan Nasional
BNPP	Badan Nasional Pengelola Perbatasan
BUMN	Badan Usaha Milik Negara
DTT	Daerah Tertinggal, Transmigras
HANKAMNAS	Pertahanan dan Keamaanan Nasional
OTEC	Ocean Thermal Energy Conversion
PLBN	Pos Lintas Batas Negara
PLN	Perusahan Listrik Negara
PPN	Perencanaan Pembangunan Nasional
TTT	Tertinggal, Terdepan, Terluar
BLT	Batas Laut Teritorial
EEZ	Exclusive Economic Zone
BLK	Batas Landas Kontinen

1.0 INTRODUCTION

Indonesia is the tropical oceans country, approximately located at latitudes less than 20 degrees, may be thought of as enormous passive solar collectors. Indonesia has 77% of the total area

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covered by the ocean with thousand islands. Most of the frontiers, remotest & outermost islands are called as 3T regions.

The 3T regions have a variety of specific natural resources, limited, as well as the environmental carrying capacity is limited. In 3T regions, both in the West and the East, Indonesia, supplying fresh water in the dry or rainy season and supply of electricity are still a problem difficult and must be addressed by the government. The problem is more complex if the supply of water and electricity associated with integrated regional development plan that includes residential areas, industry, trade, transportation, national defense and security (HANKAMNAS), and others as shown in Figure 1. Strategic management of 3T regions should be sought so that the water and electricity resources available will not be used beyond the limits of carrying capacity.

Figure 1: Scarcity of clean water (left) and electricity (right) in 3T regions in Indonesia [1-3].

This paper discusses on application of OTEC to strengthen and sustains Indonesia's national economic and defense at 3T (frontiers, remotest & outermost) regions. In this study, 2 MW OTEC in Siberut, West Sumatra, Indonesia is taken as case study.

2.0 LITERATURE REVIEW

Some researchers have studied OTEC in Indonesia such as Donny, et.al 2010 [4-5] has mentioned in their study that OTEC plants can be applied in the regions of along southern Sumatra, Java, Bali, Nusa Tenggara archipelago and in eastern Indonesia. In 2015, Donny [4-5] proposed a strategy to develop OTEC in Indonesia by taken economic and environmental issues. He stated that Indonesia has excellent ocean thermal energy conversion technology resources, especially along southern Sumatra, Java, Bali, Nusa Tenggara archipelago and in eastern Indonesia. Adrian 2015 [6] stated that OTEC could be a solution to produce electricity and also can produce fresh water and cold water for agricultural and cooling purposes especially in the tourist area in Bali. Fanny, et.al 2016 [7] studied potentially of OTEC Installation as Power Plant in West Sumatera, Indonesia. They proposed three potential locations for OTEC application as follows: Pesisir Selatan, Padang and Mentawai Islands. Delyuzar in 2016 [8] has conducted sites seawater temperature measurement in Indonesian waters by MGI Team at the following locations: Mamuju located in the Makassar Strait, Tarakan, Flores Sea, North Bali and Lembata, Nusa Tenggara Timur. Koto et.al [1-3, 9-17] studied application of OTEC in Indonesia and they stated that OTEC produced fresh water and electricity produced by OTEC was lower than current market price. Besides that, As OTEC releases a large amount of warm and cold sea water after evaporating ammonia to rotate the turbine, the discharge warm water may be used for shrimp, groupers, sea trout cultivation, cold agriculture such as strawberry, broccoli, tomato, cabbage, etc.

3.0 3T REGIONS AND GOVERNMENT PROGRAM

3.1 3T Regions

The government of the Republic of Indonesia continues to strive for development in Frontiers, Remotest & Outermost (3T) regions. Indonesia's geography covering thousands of islands spread from Sabang, Aceh to Merauke, Papua has a large number of 3T areas. Determination of 3T Regions in 2015-2019 refers to Presidential Regulation Number 131 of 2015 [18]. Based on data from the Department of Village, Remote Area Development and Transmigration (DTT), there are currently 67 districts that have small and outermost islands. Of these, there are 187 outermost districts and 122 remote areas [19]. As Indonesia has a coastline of 95,185 kilometers, it is required an extra effort to develop the 3T regions [16]. Understandably, most regions do not yet have the infrastructure as good as more advanced urban regions such as Jawa and Bali.

Frontiers and Remotest Regions

Criteria for frontiers and remotest regions are as follows:

1. Transportation access is difficult to reach and expensive due to the unavailability of roads, depending on certain schedules, depending on the weather, the only access by foot, has great natural obstacles and challenges;
2. Not available and / or very limited services for public facilities, educational facilities, health facilities, electricity facilities, information and communication facilities, and clean water facilities; and / or
3. High prices and / or difficulties in the availability of food, clothing, and shelter or housing to fulfill living needs.

Outermost Regions

Criteria for outermost small islands are islands with an area of less than or equal to 2000 km² which have basic points of geographical coordinates that connect the archipelagic sea baseline in accordance with International and National law [18].

Border Regions

The criteria for border areas with other countries are as follows:

1. As a sea area and land area which is directly adjacent to neighboring countries which includes Territorial Sea Boundaries (BLT), Exclusive Economic Zone boundaries (EEZ), Continental Shelf Boundaries (BLK), and special fisheries zone boundaries; and / or
2. As a land border area that borders directly with neighboring countries

3.2 Government Program

The 3T regions are currently the main target of the Government of the Republic of Indonesia to fulfill as follows:

1. Energy needs such as electricity,
2. Clean water,

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3. Employment fields,
4. Development of People's industries such as fisheries, agriculture and tourism.
5. Become the strongest outer defense.

In the five-year National Medium-Term Development plan, the government aims to alleviate 5,000 villages in 3T regions and make 2,000 independent villages. But in its development, there are currently 15,000 villages in the 3T regions that have developed and 2,300 independent villages were created [19].

As for developing the 3T regions is certainly not the responsibility of one agency alone. It is very necessary to cooperate with other related institutions. The 3T regions program must start from the regional government, relevant ministries and state-owned enterprises (BUMN). Moreover, BUMN in the past few years have been aggressively campaigning for the BUMN Present for the Country program. Efforts to accelerate 3T regional development should also not rely on facilitating the development of basic social infrastructure, but also improving physical and economic infrastructure.

This is expected to increase regional productivity so that in the end it supports the improvement of regional economic growth. On the other hand, according to National Development Planning (PPN) and National Development Planning Agency (BAPPENAS), the gap between regions was a complex and multi-sectorial problem. For this reason, the government will immediately carry out and support development in Indonesia, namely by strengthening regional development to the regions with the principle of 3T regions. This step is an effort to better national economic equality.

There are two programs that can be done to alleviate 3T regions, namely by building village-owned enterprises and superior village products. With the implementation of the two programs, integrity will make the village economically independent. Furthermore, each village will be able to build social facilities and public facilities so that they can be socially independent. Efforts to develop the 3T area were also carried out by the government by establishing cross-border border areas

The border region has a strategic position in the legal and economic order of a region. The border area also has important meaning because of its position directly facing other countries. In developing border areas, the government has built a cross-border post (PLBN) at seven strategic points. The existence of PLBN is not only a marker of territory but also makes trading activities more orderly. "In addition to the orderly flow of goods, human traffic is also orderly. Immigration Affairs and quarantine tax.

It is highly expected that the alleviation of underdeveloped areas can be better so as to encourage an increase in the Human Development Index, economic growth and a reduction in poverty rates

4.0 POTENTIAL OTEC IN 3T REGIONS

As stated in the Presidential Regulation Number 131 of 2015, the regions entering the underdeveloped areas in 2015-2019 are as shown in Table 1 [21]. In terms of geographical terms, OTEC is potential to be applied at the 3T regions as shown in Figure 2 such as Mentawai, Sumatera Barat (A), North of Sulawesi Utara (B), North of Maluku Utara (C) and Banda (D), Maluku, Makasar Strait (E), East Kalimantan (F), North of Bali (G), Nusa Tenggara Barat (H), Papua Barat (I), Sulawesi Tenggara (J). OTEC can be applied effectively and on a large scale to provide a source of renewable energy that is needed to cover a wide range of energy and economic issues.

Table 1: Potential of OTEC applied in 3T Regions in Indonesia [21]

No	3T Regions		OTEC
	Provinces	**Districts**	
1	Aceh	Aceh Singkil	
2	Sumatera Utara	Nias, Nias Selatan, Nias Utara and Nias Barat	A
3	Sumatera Barat	Kepulauan Mentawai, Solok Selatan and Pasaman Barat	A
4	Sumatera Selatan	Musi Rawas, Musi Rawas Utara	
5	Bengkulu	Seluma	
6	Lampung	Lampung Barat and Pesisir Barat	
7	Jawa Timur	Bondowoso, Situbondo, Bangkalan, Sampang	
8	Banten	Pandeglang, Lebak	
9	Nusa Tenggara Barat	Lombok Barat, Lombok Tengah, Lombok Timur, Sumbawa, Dompu, Bima, Sumbawa Barat, Lombok Utara	G
10	Nusa Tenggara Timur	Sumba Barat, Sumba Timur, Kupang, Timor Tengah Selatan, Timor Tengah Utara, Belu, Alor, Lembata, Ende, Manggarai, Rote Ndao, Manggarai Barat, Sumba Tengah, Sumba Barat Daya, Nagekeo, Manggarai Timur, Sabu Raijua, Malaka	G
11	Kalimantan Barat	Sambas, Bengkayang, Landak, Ketapang, Sintang, Kapuas Hulu, Melawi, Kayong Utara	
12	Kalimantan Tengah	Seruyan	
13	Kalimantan Selatan	Hulu Sungai Utara	
14	Kalimantan Timur	Nunukan, Mahakam Ulu	F

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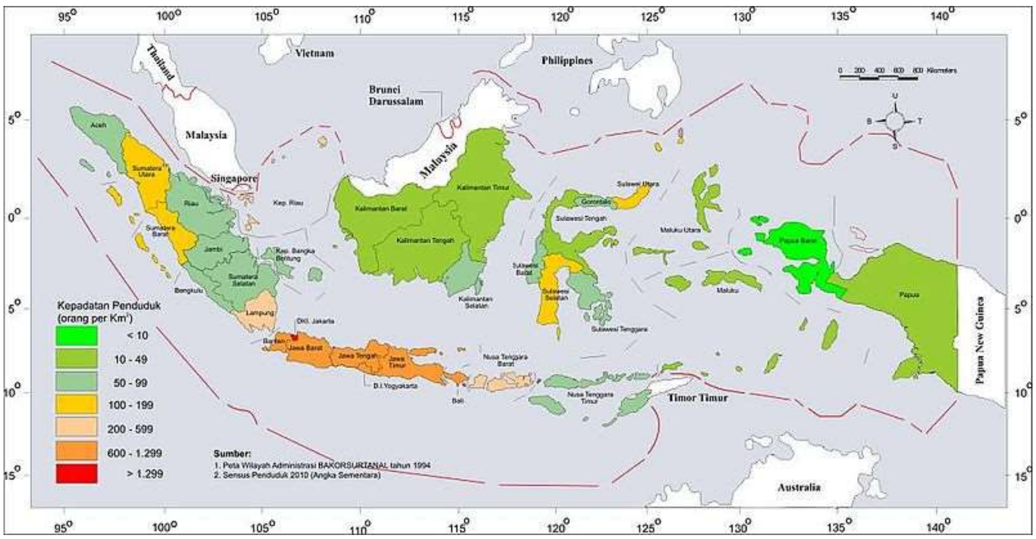
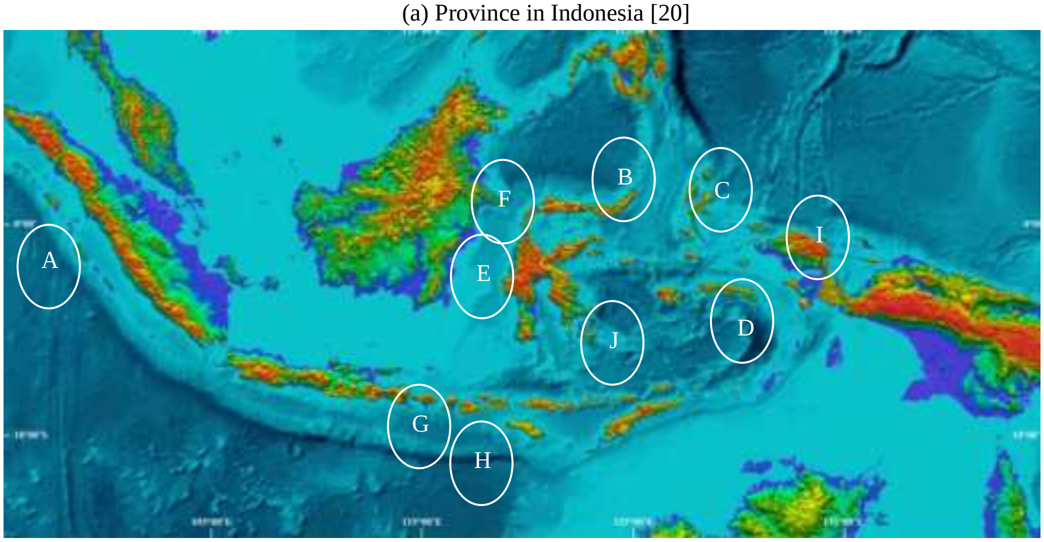
15	Sulawesi Tengah	Banggai Kepulauan, Donggala, Tolitoli, Buol, Parigi Moutong, Tojo Una-Una, Sigi, Banggai Laut, Morowali Utara	
16	Sulawesi Selatan	Jeneponto	
17	Sulawesi Tenggara	Konawe, Bombana, Konawe Kepulauan	J
18	Gorontalo	Boalemo, Pohuwato, Gorontalo Utara	B
19	Sulawesi Barat	Polewali Mandar, Mamuju Tengah	E
20	Maluku	Maluku Tenggara Barat, Maluku Tengah, Buru, Kepulauan Aru, Seram Bagian Barat, Seram Bagian Timur, Maluku Barat Daya, Buru Selatan	D
21	Maluku Utara	Halmahera Barat, Kepulauan Sula, Halmahera Selatan, Halmahera Timur, Pulau Morotai, Pulau Taliabu	C
22	Papua Barat	Teluk Wondama, Teluk Bintuni, Sorong Selatan, Sorong, Raja Ampat, Tambrauw and Maybrat	I
23	Papua	Merauke, Jayawijaya, Nabire, Kepulauan Yapen, Biak Numfor, Paniai, Puncak Jaya, Boven Digoel, Mappi, Asmat, Yahukimo, Pegunungan Bintang, Tolikara, Sarmi, Keerom, Waropen, Supiori, Memberamo Raya, Nduga, Lanny Jaya, Memberamo Tengah, Yalimo, Puncak, Dogiya, Intan Jaya, Deiyai	I



(a) Province in Indonesia [20]



(b) Potential OTEC in Indonesia [1-3]

Figure 2: Bathymetry map of Indonesia

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5.0 OTEC IN MENTAWAI ISLAND, SUMATERA BARAT, INDONESIA

5.1 OTEC Process System

Ocean Thermal Energy Conversion (OTEC) is a marine renewable energy technologies that harness the sun's energy is absorbed by the oceans to produce electricity. hot sun warms the surface water a lot more than sea water, which creates a natural temperature gradient provided the sea, or thermal energy.

OTEC is an extremely clean and sustainable technology and in some cases will even produce desalinized water as a byproduct. Like any alternative form of energy generation OTEC has its advantages and disadvantages, but it nonetheless a feasible means to achieve a future of sustainable power.

OTEC uses warm water at sea level with temperatures around 25 °C to vaporize a working fluid, which has a low boiling point, such as ammonia. Steam expands and rotating turbine coupled to a generator to produce electricity. The vapour is then cooled by seawater pumped from deeper ocean layers, where temperatures around 5 °C. The working fluid that condenses is back into a liquid, so it can be reused. It is a continuous cycle power plant. These power plants face many engineering challenges. They require deep-water sources so are only useful around coastal regions and islands. Additionally, the pumping of ocean water from up to 300 meter deep requires a large diameter pipeline. Dealing with ocean conditions is also often difficult in executing an OTEC power plant. The offshore location of these plants means they must be located on floating barges, fixed platforms, or deep beneath the sea.

There are four main types of OTEC which are open, closed, kalina and hybrid cycles [1]. All four types of OTEC can be land-based, sea-based, or based on floating platforms. The former has greater installation costs for both piping and land-use. The floating platform installation has comparatively lower land use and impact, but requires grid cables to be installed to land and has higher construction and maintenance costs. Finally, hybrid constructions combine OTEC plants with an additional construction that increases the temperature of the warm ocean water.

5.2 Closed Cycle OTEC Theory

Ocean thermal between water surface and water depth must be converted to reach maximum output from its thermal. The OTEC efficiency value can be calculated using the equation of Carnot efficiency.

$$\eta_{Carnot} = \frac{T_{max} - T_{min}}{T_{max}} \quad (1)$$

Where; η is Carnot efficiency, T_{max} is an absolute temperature of the surface water, T_{min} is an absolute temperature of the deep water

The efficiency of the cycle is determined by the temperature difference. The greater the temperature difference, the higher the efficiency. This technology is therefore worth especially in equatorial regions where differential temperatures throughout the year are at least 20 ^{0}C.

The efficiency of the cycle can be calculated

$$\eta_{Cycle} = \frac{W_{net}}{Q_H} \quad (2)$$

where; W_{net} is work output and Q_h is specific heat to the heat exchanger.

5.3 Overview of Siberut Island

Siberut is a part of Mentawai Islands which is a chain of about seventy islands and islets off the western coast of Sumatra in Indonesia. The Mentawai islands with population 76,421 people are approximately 150 km from shoreline of Sumatera Barat as shown in Figure 3 [9, 11]. The indigenous inhabitants of the islands are known as the Mentawai people. Mentawai Island has a hot and humid tropical rainforest climate, with an annual rainfall of 4,000 mm with temperatures range 22-31 °C and humidity averages 81-85%. Siberut is the largest and northernmost of the Mentawai Islands, lying 150 km west of Sumatra in the Indian Ocean. A part of Indonesia, the island is the most important home for the Mentawai people. Siberut Island has area 4,030 km^2 with population 35,091 people [9-11]. Other major islands are Sipura, North Pagai and South Pagai.

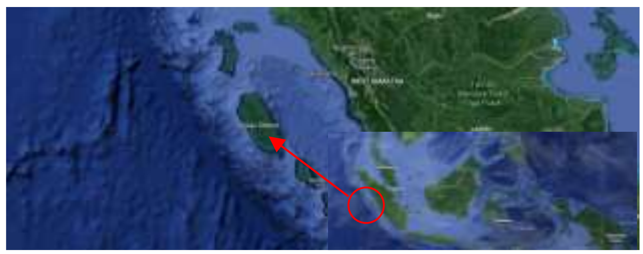

Figure 3: Schematic of the OTEC potential in Siberut Island, Sumatera Barat-Indonesia.

5.4 Surface Seawater Temperature

The Sea Surface Temperature (SST) patterns over the Mentawai region clearly demonstrate the effect of the monsoons cycle as shown in Figure 4. The surface temperatures are influenced by the Southwest and Northeast monsoons. The SST increase from January to reach the maximum on May with 31 0C before down to the minimum at 28 °C. The average SST is at 29.8 °C.

5.5 Seawater Profile Temperature

Figure 5 shows profile temperatures at different water depths in Sumatera Barat. The temperature profiles show a pronounced thermocline between 100 and 125 m with an almost homogeneous upper layer. At some stations off the west coast, temperatures below 10 °C were measured deeper than 400 meters [9-11].

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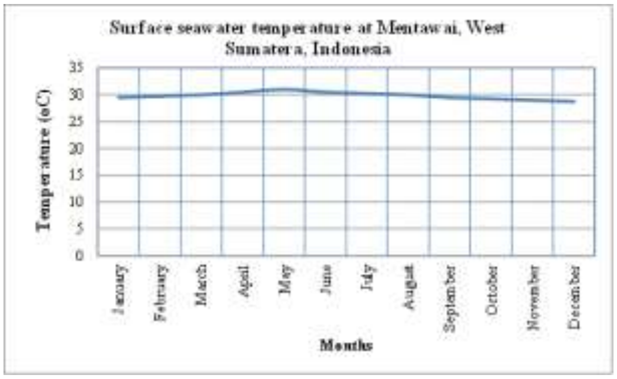

Figure 4: Mean monthly surface seawater temperature in Mentawai Islands, Sumatera Barat-Indonesia.

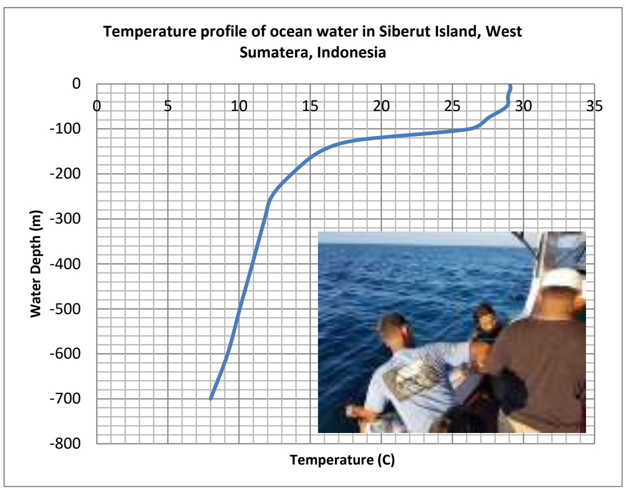

Figure 5: Temperature profile of ocean water in Siberut Island in Sumatera Barat-Indonesia.

4.6 OTEC Closed System in Siberut

In the study, the performance was simulated using Subsea Pro. The software was developed by Ocean and Aerospace Research Institute, Indonesia. The simulation was based on following assumptions:

- Surface temperature inlet was assumed 28 °C (the lowest surface temperature in Indonesia) and the temperature outlet was setup 25 °C.
- The evaporation and condensation ammonia pressures rose and decreased were assumed 0.06 bar.
- The surface and deep seawater pressures decreased were assumed 0.3 and 0.72 bar respectively.
- The evaporation and condensation ammonia temperatures were set up 25 and 8 °C
- The outlet surface and deep sea water temperatures were set up 25and 9 °C
- Turbine and generator efficiencies were assumed 75 and 94 %, respectively
- Working fluid was using pure ammonia
- Depth of inlet sea water was 700 meter.
- The inlet surface and deep sea water temperatures are 28 and 6.2 °C, respective

Figure 6 shows a simplified schematic diagram of a 2 MW plant closed cycle OTEC system. The principal components are the heat evaporator, condenser, turbine and generator, and seawater supply system. The figure did not included ancillary devices such as separators to remove residual liquid downstream of the evaporator and subsystems to hold and supply working fluid lost through leaks or contamination.

Heat transfer from high temperature occurs in the evaporator, producing saturated ammonia. The hot water is required 117 kW to pumped from surface seawater. Electricity is generated when this ammonia gas expands to lower pressure through the turbine. Latent heat is transferred from the vapor to the low temperature from deep sea water in the condenser and the resulting liquid is pressurized with a pump with 130 kW from wind energy. The low temperature of ammonia is pumped with 33 kW from solar energy.

Figure 7 show simulation results of OTEC performance to generate 2 MW plant of electrical power in Mentawai, Sumatera Barat-Indonesia. In the simulation, the inlet surface and deep sea water temperatures are 28 and 6.2 °C, respectively. The results simulation shows that the suitable mass flow rate of the working fluid is 72 kg/sec. The surface and deep seawater flow rates were founded 6000 and 6600 kg/sec. The simulation shows several founding as follow:

- Long Mean Temperature Difference (LMTD) is 18.75
- Investment for generating electrical power is 0.314 $/kWh
- The Carnot efficiency of ammonia saturation is 6 percent
- The cycle efficiency of ammonia saturation is 0.41 percent

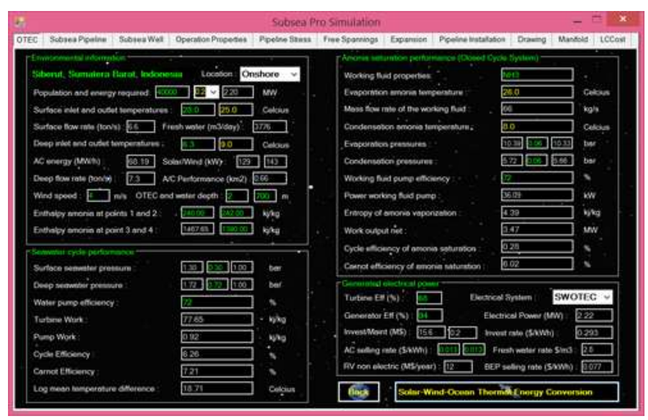

Figure 7: OTEC simulation results in Siberut, Sumatera Barat.

Siberut island has potential OTEC due to the gradient temperature more than 20 °C which can produce electricity and fresh water. OTEC is benefit to the needs of the population in the Siberut island, Indonesia as shown in Figure 8. OTEC also provide a major economic impact through affordable prices or cheaper than price in the field right now.

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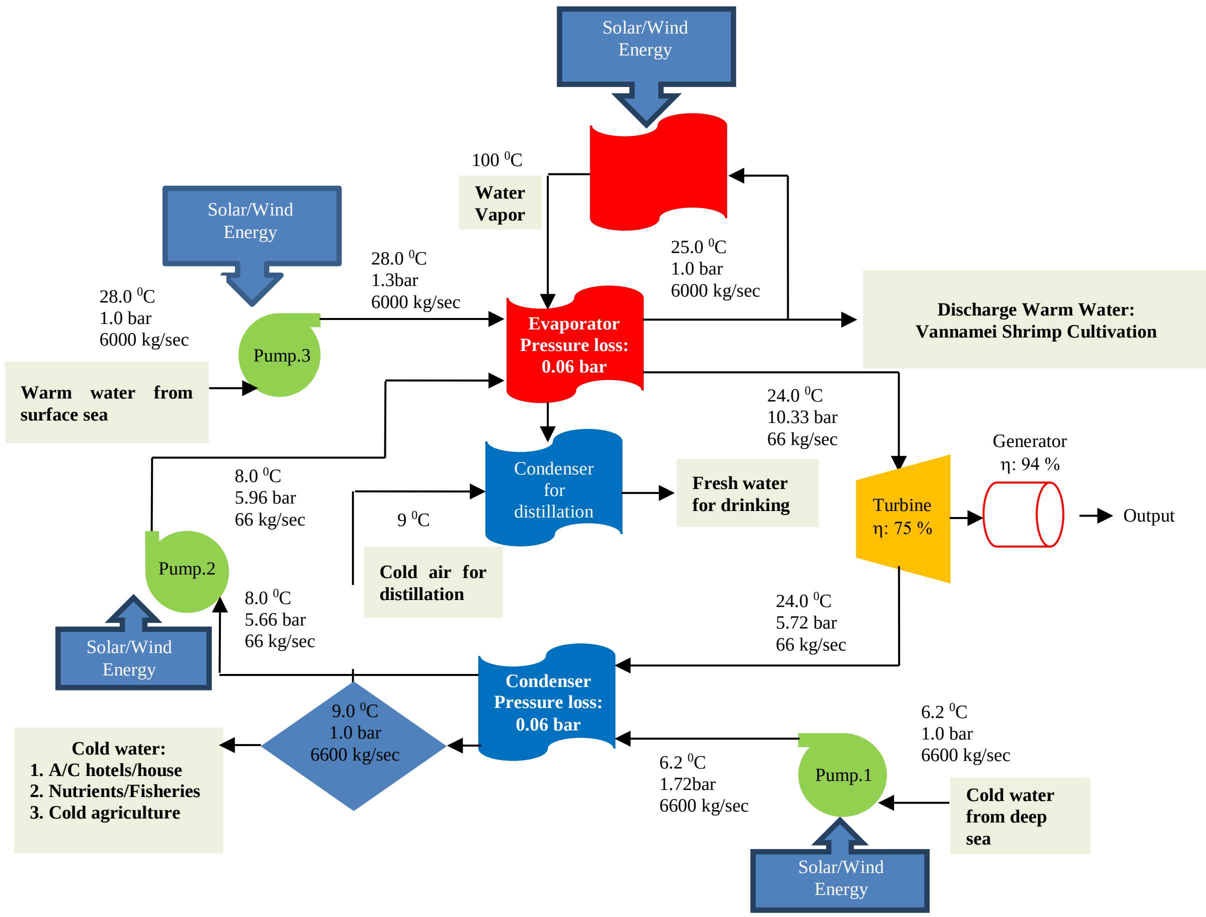

Figure 6: Detailed flow conditions for a single-stage 2 MW plant in Siberut, Sumatera Barat-Indonesia.

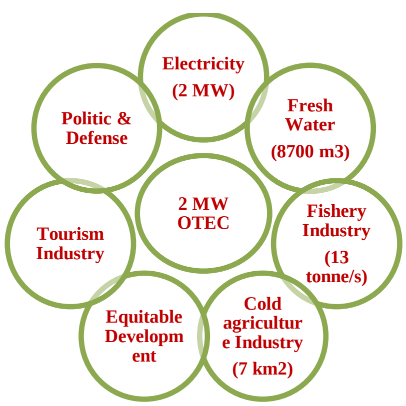

Figure 8: Benefit of 2 MW OTEC at Siberut Island

Electricity

For electricity, the prediction using OTEC in electricity rates in 3T regions is cheaper than the rate of Perusahan Listrik Negara (PLN) as shown in Figure 9.

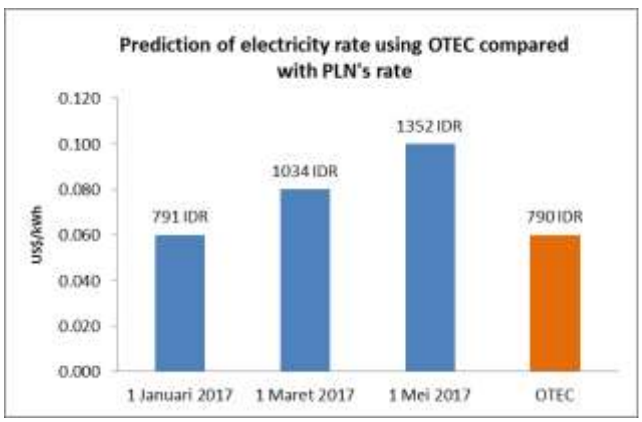

Figure 9: Electricity rate using OTEC compared with rate of Perusahan Listrin Negara (PLN) in Siberut, Sumatera Barat.

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Fresh Water

The system can produce 8730 m3 per day of fresh water for drink after distillation. Prediction price of clean water using OTEC is also much cheaper than the price of the field at this time as shown in Figure 10.

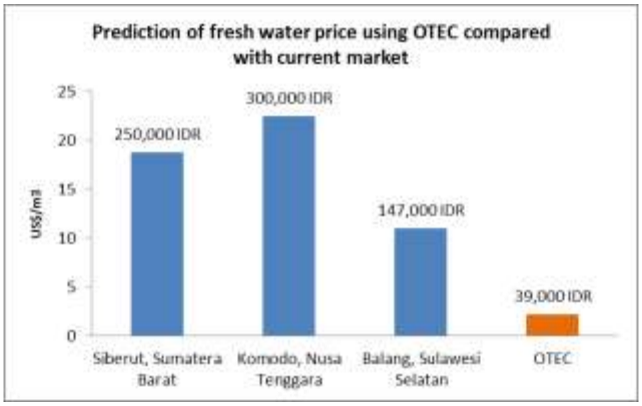

Figure 10: Electricity rate using SWOTEC compared with rate of Perusahan Listrin Negara (PLN) in Siberut, Sumatera Barat, Indonesia.

Fishery Farms

The system can also produce 13000 kg per second seawater which can be used for fish farms. As local people lives from fishing, therefore the waste seawater can be reused for fish, prawn and lobster farming. This help local to reduce cost for fishing and also increase the productivity and efficiency of local people.

The discharge warm water from 2MW OTEC is potential to irrigate 1.01 km2 of extensive, 0.459 km2 of semi intensive and 0.389 of intensive shrimp farms. The economic impact generated from shrimp farm is US$ 3.4 million [16]. The discharge cold water is also potential to irrigate sea trout farms.

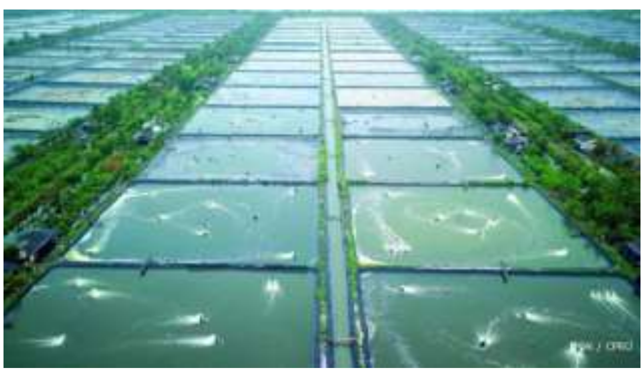

Figure 11: An example of fishery industry [22]

Cooling System

The OTEC system can produce 7.0 km^2 of green-house cooling system for tourism industries and cold agriculture. The technology and operation of the OTEC Refrigeration system is very easy. First, sea water is extracted from the sea at a certain depth to condense ammonia. The discharge cold sea water is then used to cool the fresh air, which in turn is distributed throughout the building's air conditioning system.

The cold air can be channeled to hotels and resorts as natural air conditioners without using an air conditioner (AC) system. This will reduce investment costs, operating costs and maintenance of hotels and resorts. Without relying on facilities, indirectly, it can provide cheaper hotel and resort rates compared to using air conditioning.

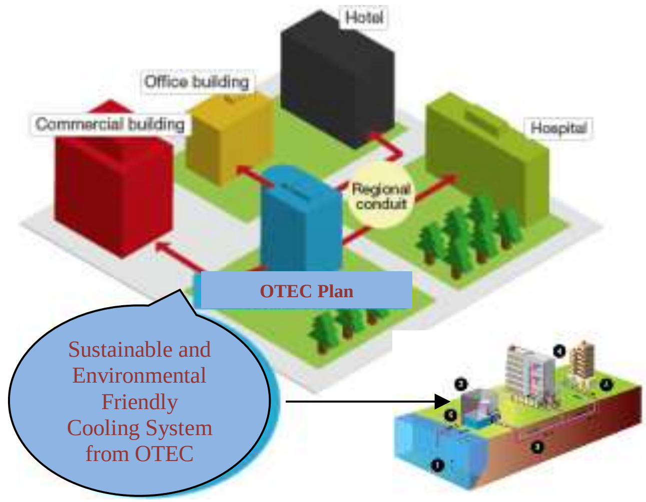

Figure 12: Sustainable and Environmental Friendly Cooling System [23]

Education National Program

Education is the most important thing in advancing an area, as we know the area which is classified as the Frontiers, Remotest & Outermost (3T) regions. Education is the main way for the 3T region to grow like the big cities in general. In addition to the problem of educators, access such as transportation and communication to education is very less a problem for the implementation of education in the 3T regions. As OTEC can have a big impact on building all infrastructures to support education, national education programs reserved by the government will be easier to implement.

National Defense and Security

National defense and security is the most important thing in advancing a country, as we know areas classified as frontiers, Remotest & Outermost (3T) areas. The defense and security advice for the 3T region is not comparable to large cities in general. In addition to equipment problems, access to communication and transportation is very less a problem for defense implementation in the 3T area. OTEC can have a major impact on the construction of all facilities and infrastructure such as integrated AIS and Radar system as shown in Figure to support defense, the HANKAMNAS program launched by the government will be easier to implement.

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Figure 13: An Example application of AIS and Radar system [24 - 28]

Cold Agriculture

The OTEC system can produce large green-house cooling system. As local people lives from agriculture farmer, therefore the cold water waste seawater can be reused for cold vegetable and fruit plantation such as green house of strawberry, carrot, broccoli. These opportunities help local people to increase productivity, income and efficiency of local people.

Figure 14: An example green-house strawberry and carrot plantations [1].

5.0 CONCLUSION

In conclusion, this paper discussed potential of OTEC to solve the critical issues such as availability of fresh water, electricity, food, employment, education, defenses in the 3T regions. As case study, 2MW OTEC for Siberut Island, Sumatera Barat, Indonesia was analyzed. The results founded that Siberut island, Sumatera Barat, Indonesia has gradient temperature more than 20 °C. It means they are suitable to install OTEC. OTEC technology is high potential to be applied in the islands due to giving lower electricity and fresh water rates compared with current rate. The 2MW OTEC has great benefits to proves drinking fresh water, opened opportunity for fishery industry and agriculture industry, equitable infrastructure development, development tourism Industry and strengthening Politic & Defense

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