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Sea Temperatures Profiles for Ocean Thermal Energy Conversion in Siberut-Mentawai, Sumatera Barat, Indonesia

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ABSTRACT

Ocean Thermal Energy Conversion (OTEC) is a clean marine renewable energy using temperature difference between the sea surface and the deep ocean to rotate a generator to produce electrical energy. As Indonesia is an equatorial country located at latitudes less than 20 degrees covered by 77 % ocean, thousand islands, strain and many difference of topography, OTEC is very compatible to be built in Indonesia. This paper discussed on sea temperature profiles at Siberut island-Mentawai, Sumatera Barat-Indonesia. The Siberut island-Mentawai is one of potential areas for OTEC in Indonesia. The Siberut island-Mentawai has a hot and humid tropical rainforest climate, with an annual rainfall of 4,000 mm with temperatures range 27 - 31 ^{0}C and humidity averages 81 - 85%. The sea temperature was measured using thermocouple, It founded that the Siberut island-Mentawai has potential OTEC due to the gradient temperature more than 20 ^{0}C.

KEY WORDS: *Siberut Island, West Sumatera, Indonesia, Ocean Thermal Conversion Energy.*

NOMENCLATURE

OTEC	Ocean Thermal Energy Conversion
IR	Indonesian Rupiah
SST	Sea Surface Temperature
NOAA	National Oceanic and Atmospheric Administration
AVHRR	Advanced Very High Resolution Radiometer

1.0 POTENTIAL OTEC IN INDONESIA

Ocean Thermal Energy Conversion (OTEC) is a marine renewable energy technology with zero-emission. OTEC uses temperature difference between the sea surface and the deep ocean to rotate a generator to produce electrical energy. The sea surface is heated continuously by sunlight from surface up to 100 m. OTEC is capable of generating electricity day and night, throughout the year, providing a reliable source of electricity.

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.

OTEC is an extremely clean and sustainable technology and

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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 is one of the world's largest renewable energy resources and is available to around the tropical countries. Indonesia is an archipelago island nation along the equator and tropical areas, lies between the Indian Ocean and the Pacific Ocean. With Indonesia's climate tends to be relatively even throughout the year, therefore Indonesia has OTEC energy source is provided plentiful and constantly replenished during the sun was shining and the ocean currents naturally present.

OTEC obviously can have huge application in tropical areas such as Indonesia, where the required water temperatures occur, providing power, fresh water, air conditioning and more. Indonesia is the tropical oceans country, approximately defined by latitudes less than 20 degrees, may be thought of as enormous passive solar collectors.

As the Indonesia has 77 % of total area covered by the ocean, OTEC can be done effectively and on a large scale to provide a source of renewable energy that is needed to cover a wide range of energy issues. Figure 1 shows the schematic of OTEC potential in Indonesia. As shown in the figure, East Indonesian has lot of deeper seas and smaller islands than West side. The West side has higher wave height than East part due to faced Indian Ocean directly. Therefore, it was founded that most potential areas for OTEC are located in the East Indonesia. There are six potential areas for OTEC application as shown in Table 1.

Table 2 shows surface temperature and deep sea temperatures on several locations in Indonesia which found temperature difference more than 20 ^{o}C. The average surface temperature was about 29 ^{o}C and the deep sea temperature between 8 – 6 ^{o}C.

Table 1: Potential areas for OTEC in Indonesia.

No	Potential location
A	Sumatera Baarat: Mentawai islands
B	Sulawesi Utara such as Karangkelong
C	Maluku Utara such as Morotai Island
D	Maluku Selatan such as Taliabu, Buru and Seram islands
E	Kalimantan Timur
F	Sulawesi Tenggara
G	Nusa Tengggara Barat
H	Papua Barat
I	Nusa Tengggara Timur

Table 2: Temperatures on the surface and 700 m of depth water at several locations in Indonesia.

Location	T_{Max}, (^{0}C)	T_{Min} (^{0}C)
Mentawai, Sumatera Barat	29.50	8.20
Sulawesi Utara	29.00	6.00
Papua Barat	29.00	6.00
Morotai Sea	29.00	6.00
South of Maluku	29.00	7.00

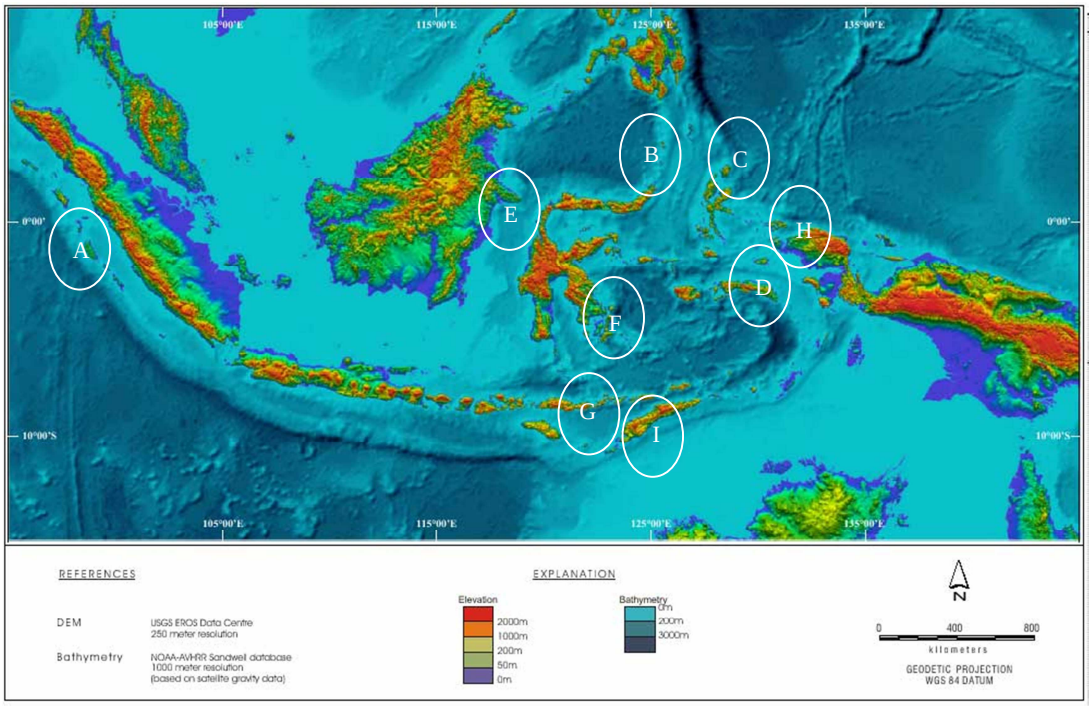

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Figure 1: Bathymetry map of Indonesia [1 & 2)].

3. POTENTIAL OTEC IN INDONESIA

Some researchers have studied OTEC in Indonesia. Achiruddin, et.al 2010 [3)] 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)] 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 [5)] 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 [6)] 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 [7)] 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 has studied feasibility OTEC in Indonesia such as Mentawai [8)], Karangkelong [9)], Maluku [10)] and Morotai [11)].

2.0 GEOGRAPHY AND ISSUES IN SIBERUT ISLAND

2.1 Geography of Siberut Island

Siberut is the largest and northernmost of the Mentawai Islands, lying 150 kilometres 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 km2 with population 35,091 people. Siberut Island has a hot and humid tropical rainforest climate, with an annual rainfall of 4,000 mm with temperatures range 22 - 31 ^{0}C and humidity averages 81-85%.

2.3 Electricity and Clean Water Crisis

In small or outermost islands in the West, Indonesia, supplying fresh water in the dry or rainy season and supply of electricity is 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, Hankamnas, and others. Strategic management of remote islands and outermost should be sought so that the water and electricity resources available will not be used beyond the limits of carrying capacity.

Siberut island is one of isolated islands or outermost islands have a variety of specific natural resources, limited, as well as the environmental carrying capacity is limited as shown in Figure 2. In the Siberut island, price of fresh water is IR 30,000 per gallon (20 liters).

Figure 2: Clean water crisis in Siberut island, Sumatera Barat-Indonesia.

2.0 SURFACE SEAWATER TEMPERATURE

The Sea Surface Temperature (SST) patterns over the Indonesian region clearly demonstrate the effect of the monsoon cycle as shown in Figure 3. The dry season from June to October is influenced by the Australian continental air masses due to the Southwest monsoon. The rainy season from November to March is caused by South China Sea and Pacific Ocean air masses due to the Northeast monsoon.

The Southwest monsoon season from June to October brings 70% of the country's annual rainfall. The satellite data shows that the sea surface temperatures are 25 – 27 0C, which are observed in the Arafuru Sea, Banda Sea and off the southern part of the Jawa-Nusa Tenggara Island chain. Strong southwesterly winds induce divergence along the coasts of the Jawa-Nusa Tenggara Island chain and within the Banda Sea, and generate upwelling, reducing the SST. In addition, strong winds enhance vertical mixing, also reducing the SST. Within the internal Indonesian Seas, warmer temperatures are clearly observed. Although the Timor Sea shows some cooling, it lasts only a month, leaving it a warm zone bracketed by the colder Arafuru Sea and Jawa Current region. Cooling during the southeast monsoon is not uniform over the southern areas. The Timor Sea is anomalously warmer than areas to the west or east, a condition that persists throughout the year. Conditions are reversed during the northwest monsoon with colder temperatures observed in the South China Sea.

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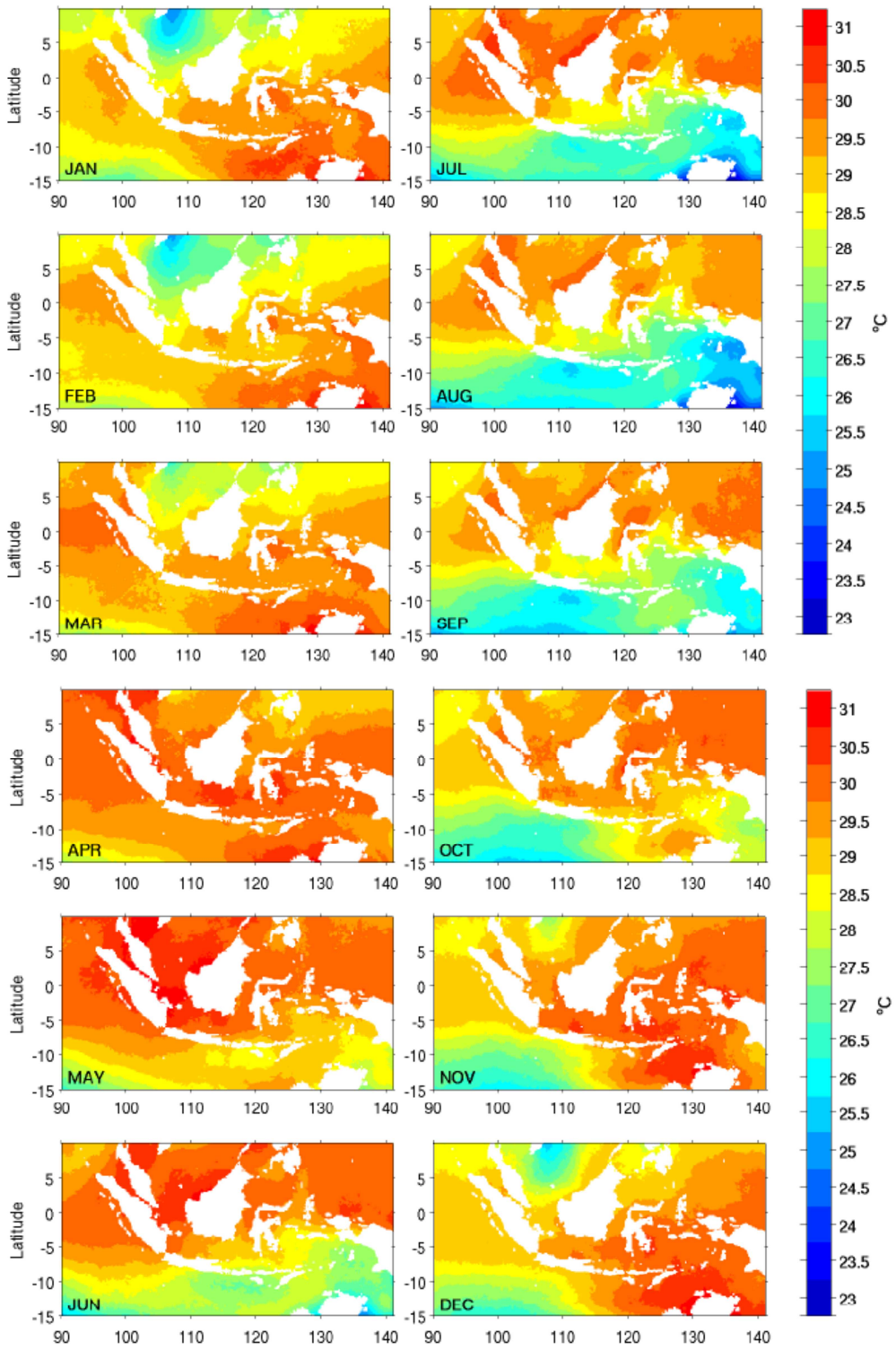

Figure 3: Monthly mean of SST derived from NOAA-AVHRR based on monthly mean data from January 1998 to December 2003 [R. Dwi Susanto. et.al, 2006 & Koto, 2016]

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3.0 OCEAN TEMPERATURE PROFILE IN SIBERUT ISLAND

The activity is collaboration research between the International Socirty of Ocean, Mechanical and Aerospace -scientists & engineers- (ISOMAse), Engineering Faculty of Universitas Andalas, Engineering Faculty, Universitas Riau, Mechanical Engineering Faculty, Universiti Teknologi Malaysia and Ocean & Aerospace Research Institute Indonesia

The feasibility study was conducted at Siberut island (S 01^o 34.660, E099^o 14.443) Mentawai, Sumatera Barat as shown in Figure 5. The location was taken 3 hours from Padang using fast boat with 30 knot of speed.

Figure 4: Potential location of OTEC in Siberut Island, West Sumatera-Indonesia.

3.1 Preparation and Facilities Testing

The experiment was prepared and laboratory test in the Mechanical Engineering, Universitas Andalas as shown in Figure 6. In order to find the suitable location, team also called a local people (Mr.Salman) who has long experiences in Siberut channel.

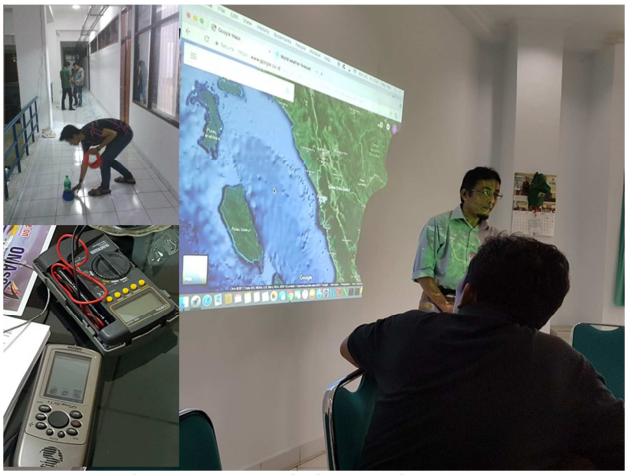

Figure 5: Laboratory test and choosing location at Engineering Faculty of Universitas Andalas, Padang.

3.2 Transportation and Site Location Condition

The experiment facilities were carried out to Siberut island from Padang using fast ferry. The team departed early morning at 6 am to avoid harsh weather during transportation and measuring.

Figure 6: Air pasang and surut. at the Siberut island, Mentawai Sumatera Barat, Indonesia.

Figure 6: On board to the Siberut island, Sumatera Barat, Indonesia.

3.3 Temperature Measurement

The temperature profiles were measured using thermocouple. Theoretically, a thermocouple produces a temperature-dependent voltage as a result of the thermoelectric effect, and this voltage can be interpreted using multimeter as shown in Figure 7 to measure temperature due to two dissimilar conductors forming electrical junctions at differing temperatures.

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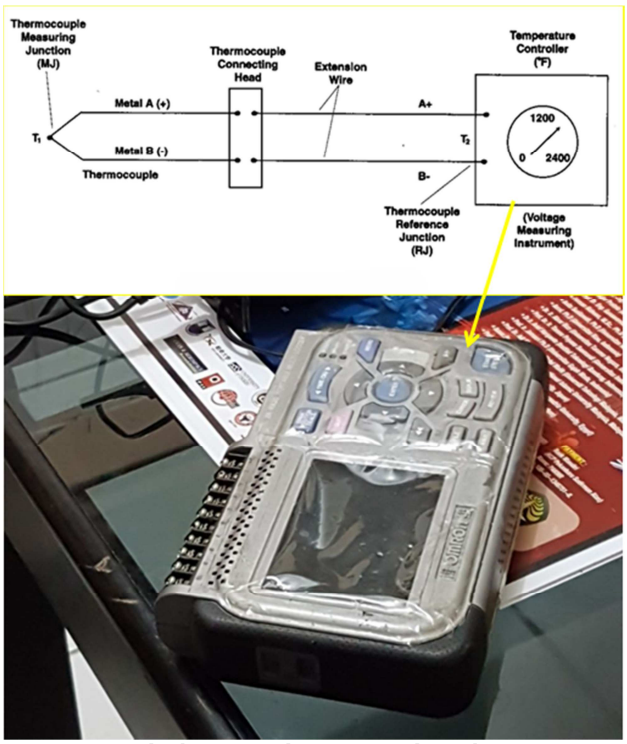

Figure 7: Single thermocouple circuit used at Siberut, Sumatera Barat-Indonesia on progress

Figure 8 shows profile at different water depths at Siberut island, Sumatera Barat. The temperature different between surface and seabed was more than 20 ^{o} Celsius.

Figure 7: Experiment of surface and deep sea water at Siberut, Sumatera Barat-Indonesia on progress.

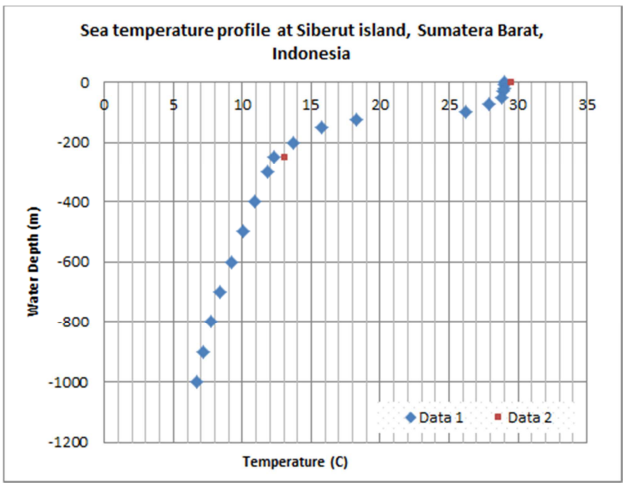

Figure 8: Sea temperature profiles at Siberut Island in Sumatera Barat, Indonesia.

4.0 CONCLUSION

In conclusion, this paper discussed potential of 100 kW OTEC in Siberut island Sumatera Barat, Indonesia. The results founded that Siberut island, Sumatera Barat, Indonesia has gradient temperature more than 20 ^{0}C. It means they are suitable to install OTEC.

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