

Potentially of Ocean Thermal Energy Conversion (OTEC) Installation as Power Plant in West Sumatera - Indonesia

FANNY OCTAVIANI, MUSWAR MUSLIM, AYOM BUWONO, DANNY FATURACHMAN

Marine Engineering Department

Darma Persada University

Jl. Radin Inten II, Pondok Kelapa, Jakarta – 13450

INDONESIA

muswar_2000@yahoo.com <http://www.unsada.ac.id>

Abstract: - Ocean Thermal Energy Conversion (OTEC) is a field of science that is still less developed in the area of renewable energy sources for electricity utilization. Yet the potential of the OTEC is very large, especially in countries whose land is crossed by the equator. This study focuses on one part of the region of Indonesia which has the potential OTEC that is large enough in the area of West Sumatera. There are several points West Sumatera region that has the potential for the development of electric power installation on the utilization of seawater temperature difference waterwheel region of western Sumatera, especially the West Sumatera. From depth size coastline is very adequate for the OTEC plant was built.

Key-Words: - Indonesia, OTEC, power plant, renewable energy, seawater temperature, West Sumatera

1. Introduction

OTEC offers one of the most benign power production technologies, since the handling of hazardous substances is limited to the working fluid (ammonia), and no noxious by-products are generated. OTEC requires drawing seawater from the mixed layer and the deep ocean and returning it to the mixed layer, close to the thermo cline, which could be accomplished with minimal environmental impact. The carbon dioxide out-gassing from the seawater used for the operation of an OC-OTEC plant is less than 1% of the approximately 700 gram/kWh amount released by fuel oil plants. The value is even lower in the case of a CC-OTEC plant.

To have effective heat transfer it is necessary to protect the heat exchangers from bio fouling. It has been determined that bio ouling only occurs in OTEC heat exchangers exposed to surface seawater. Therefore, it is only necessary to protect the CC-OTEC evaporators. Chlorine (Cl_2) has been proposed along with several mechanical means. Depending upon the type of evaporator, both chemical and mechanical means could be used.

Other potentially significant concerns are related to the construction phase. These are similar to those associated with the construction of any power

plant, shipbuilding and the construction of offshore platforms. What is unique to OTEC is the movement of seawater streams with flow rates comparable to those of rivers and the effect of passing such streams through the OTEC components before returning them to the ocean. Both ammonia and chlorine can damage the eyes, skin, and mucous membranes, and can inhibit respiration. Ammonia is used as a fertilizer and in ice skating rink refrigeration systems. Chlorine is used in municipal water treatment plants and in steam power plants. Chlorine can be generated in situ; therefore storage of large quantities of chlorine is not recommended.

OTEC plant construction and operation may affect commercial and recreational fishing. Fish will be attracted to the plant, potentially increasing fishing in the area. Enhanced productivity due to redistribution of nutrients may improve fishing. However, the losses of inshore fish eggs and larvae, as well as juvenile fish, due to impingement and entrainment and to the discharge of biocides may reduce fish populations. The net effect of OTEC operation on aquatic life will depend on the balance achieved between these two effects. Through adequate planning and coordination with the local community, recreational assets near an OTEC site may be enhanced.

Other risks associated with the OTEC power system are the safety issues associated with steam electric power generation plants: electrical hazards, rotating machinery, use of compressed gases, heavy material-handling equipment, and shop and maintenance hazards. Because the CC-OTEC power plant operates as a low-temperature, low pressure Rankine cycle, it poses less hazard to operating personnel and the local population than conventional fossil-fuel plants. It is essential that all potentially significant concerns be examined and assessed for each site and design to assure that OTEC is an environmentally benign and safe alternative to conventional power generation. The consensus among researchers is that the potentially detrimental effects of OTEC plants on the environment can be avoided or mitigated by proper design.

2. Problem Formulation

Indonesia is the tropical oceans country, approximately defined by latitudes less than 20 degrees, may be thought of as enormous passive solar collectors, and the amount of available OTEC energy has often been evaluated on the basis of how much solar radiation is absorbed by the upper layer of the oceans. This method is flawed in many respects: for example, a strictly renewable OTEC resource should be limited by the supply of deep cold seawater from the polar regions; it also leads to extraordinarily optimistic (large) numbers, with convertible energy in one 1-degree-by-1-degree mesh element of a latitude-longitude grid amounting to the electricity production of a large developed country (say 5 quads, or 5×10^{11} kWh, per year). More sober estimates are typically three orders of magnitude smaller, but still represent a potential resource globally comparable to the World's current electricity output.

3. Problem Solution

A survey of suitable OTEC power plant locations shows that temperature difference large enough for OTEC, approximately correspond to latitudes less than 20 degrees.

That arguments make it clear that Indonesia, a country of 1.9 million km² stretching from latitudes 6°08' N to 11°15' S and longitudes 94°45' E to 141°05' E, globally has excellent and potentially significant OTEC resources. Moreover, the great number of islands included in the Indonesian archipelago define a sea area about four times larger than the country itself, on the basis of a 200-

nautical-mile Exclusive Economic Zone (EEZ) as number third in the world.

The development of OTEC resources is also critically dependent upon the accessibility of the deep cold seawater heat sink, i.e. on the steepness of the coastal seafloor. Coincidentally, a rapidly dropping seafloor often corresponds to excellent wave power resources as well. Sea depths around southern Sumatera, Java and eastern Indonesia quickly exceed 1,000 m as one moves away from shore. In some areas, a depth of 500 m is reached within only 2 km from the coastline. Global Indonesian bathymetric features are shown in Figure 1.

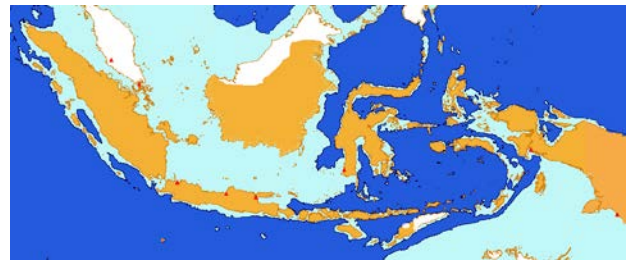


Figure 1. The steepness (1,000 m or more depth) of the coastal seafloor of Indonesia as OTEC resources

The absence of typhoons in Indonesia is a very positive point, since the OTEC resource often position in regions of active tropical storms. In other countries, such as the Philippines, the frequent occurrence of violent typhoons represents a major hurdle to the deployment of OTEC plants, whether on platforms (with delicate connections between platform and cold water pipe, or between platform and power cable) or on land, in the path of storm surges.

Indonesia is a country of active volcanism, however: earthquakes and tsunamis consequently may happen. Such events are very rare, though they are potentially violent, as historical records show. OTEC plants deployed on floating platforms would definitely be spared from earthquakes or tsunamis. Land-based plants can be designed with state-of-the-art guidelines, and should only suffer major damage during the most catastrophic events, i.e. when it could be argued that virtually no structure on land or near the shoreline would be safe from destruction, thus, it may be unreasonable to rule out OTEC plants in those areas without ruling out any industrial infrastructure at all.

The temperature of surface seawater around Indonesia water in all year mostly between 29 – 31 °C as shown in Figure 2, and candidate OTEC of temperature difference more than 20 °C in Western of Sumatera found at depth between 500 – 800 meter.

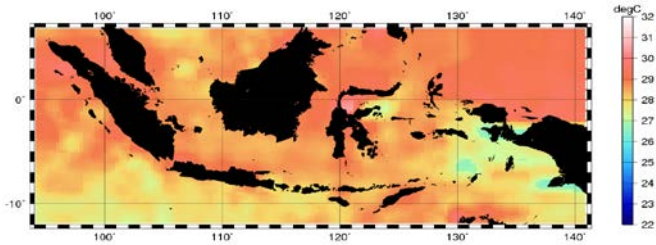


Figure.2. Sea surface temperature

ESTIMATION OF POTENTIAL OF OTEC IN INDONESIA

Indonesia has coastlines totalling 95,181 km in length making it the country with fourth longest coastline in the world, based on The United Nations (UN) announced in 2008.

Length of coastline of Indonesia : 95,181 km

Potential OTEC about 70% of coastline of Indonesia: $0.7 \times 95,181 = 66,627$ km

Distance between 100 MW OTEC plant : 30 km

Estimation OTEC potential in Indonesia :

$$[66,627 / 30] \times 100 \text{ MW} = 222,089 \text{ MW} =$$

222 GW of electricity

Capacity factor (CF) of OTEC to produce electricity a year is 0.8 that mean

OTEC has potential about:

$$0.8 \times 24 \times 365 \times 222 \text{ GW} = 15,557,760 \text{ GWh or } 15,557 \text{ TWh.}$$

Indonesia Over View

The Republic of Indonesia is a country in Southeast Asia and Oceania. Indonesia comprises 17,508 islands, and with an estimated population today (2015) of around 245 million people, it is the world's fourth most populous country, and has the largest Muslim population in the world.

Indonesia consists of 33 provinces, five of which have special status. Each province has its own political legislature and governor. The provinces are subdivided into regencies (*kabupaten*) and cities (*kota*), which are further subdivided into sub districts (*kecamatan*), and again into village groupings (either *desa* or *kelurahan*). Following the implementation of regional autonomy measures in 2001, the regencies and cities have become the key administrative units, responsible for providing most government services. The village administration

level is the most influential on a citizen's daily life, and handles matters of a village or neighborhood through an elected *lurah* or *kepala desa* (village chief).

The provinces of Aceh, Jakarta, Yogyakarta, Papua, and West Papua have greater legislative privileges and a higher degree of autonomy from the central government than the other provinces. The Acehnese government, for example, has the right to create an independent legal system; in 2003, Yogyakarta was granted the status of Special Region in recognition of its pivotal role in supporting Indonesian Republicans during the Indonesian Revolution. Papua, formerly known as Irian Jaya, was granted special autonomy status in 2001. Jakarta is the country's special capital region.

Population

Over 200 years, the population of Indonesia has steadily grown from 18.3 million in 1800 to 40.2 million in 1900, to 205.8 million in 2000. Over the past fifteenth years, the population went up from 205 million to 245 million.

POTENTIAL OF OTEC ON INDONESIAN AREA

Selling by products of OTEC (DW) will become additional income for investors and production cost of electricity become lower year by year. This is could be understand by formula of leveled production cost of electricity:

$$P = \{ (CC \times f) - DW \} / (8760 \times CF \times RP)$$

Where:

P : electricity price per kWh

CC : capital cost

f : fixed annual charge (on loan)

DW : Income from selling of DOWA

CF : capacity factor

RP : rate power plant

This study will be investigate OTEC resources on West Sumatera as candidate to develop pilot project 5 MW OTEC plant. Data for sites locations necessary to continuously looking for data in table 1.

Table 1. General data West Sumatera

No.	Items	Number
1.	Population (people)	
	- 2011	4,904,460
	- 2012	4,957,719
	- 2013	5,617,977
2.	Tourist Visit (foreign country)	
	- 2011	30,340
	- 2012	36,953

	- 2013	44,135
3.	Electricity Production (Mwh)	
	- 2011	2,909,200
	- 2012	3,177,200
	- 2013	3,344,600
4.	Electricity Supply (Mwh)	
	- 2011	2,403,090
	- 2012	2,649,070
	- 2013	2,788,680
5.	Water Demand (M ³)	
	- 2011	47,851,000
	- 2012	54,306,000
	- 2013	156,128,000

Source: BPS (Badan Pusat Statistik)

Location for OTEC in West Sumatera

West Sumatera position in the middle of the western coast of Sumatera, and has an area of 42,297.30 km². Geographic features include plains, mountainous volcanic highlands formed by the Bukit Barisan mountain range that runs from north-west to south-east, and an offshore island archipelago called the Mentawai Islands. The West Sumatera coastline faces the Indian Ocean and stretches 375 km from North Sumatera province in the north-west to Bengkulu in the south-east.

West Sumatera is the best destination for tourism, with natural attractions of the mainland include the tropical forests, mountains, volcanoes, lakes, valleys, rivers & waterfalls in the highlands, the fauna and flora, and the beaches around Padang and Mentawai Islands a popular destination for surfers all over the world.

The Mentawai Islands are a chain of about seventy islands and islets off the western coast of Sumatera in Indonesia. Siberut (4,030 km²) is the largest of the islands. The other major islands are Sipura, North Pagai (*Pagai Utara*) and South Pagai (*Pagai Selatan*). The islands lie approximately 150 km off the Sumatera coast, across the Mentawai Strait.

Based on bathymetry and user of electricity and by-product of OTEC, elected 3 (three) areas in West Sumatera as candidate to develop 5 MW OTEC plant.

Temperature surface and deep seawater around 3 locations on January only until depth 200 m. January is the peak of rainy season in West Sumatera, temperature surface seawater about 29 °C. Even temperature on July not available now, temperature of surface seawater on July higher than temperature on January. For more depth of seawater necessary to take new data before build OTEC

plant. Temperature data at western of Siberut Island (ordinate 01 N and 97.5 E) shown until depth 1000 m.

Candidate locations as shown in figure 3, and temperature of seawater as shown in table 2.

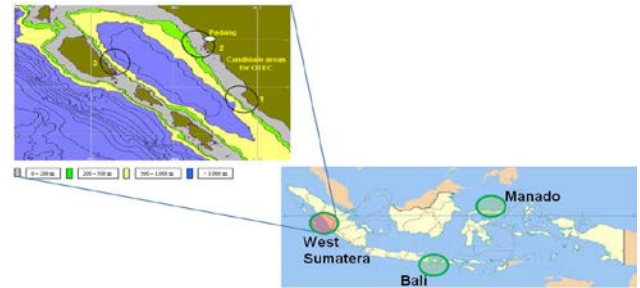


Figure 3. Three locations as candidate for OTEC plants in West Sumatera

Table 2. Coastline Temperature on West Sumatera

Depth (m)	Mean (°C)	Max (°C)	Min (°C)	Num Sample	Standart Deviation
0	29.05	30.80	27.20	15	0.78
10	29.09	30.50	28.26	16	0.54
20	28.97	30.20	28.20	17	0.50
30	28.90	29.90	27.45	17	0.57
50	28.82	29.40	28.20	14	0.36
75	27.54	29.20	22.66	17	2.03
100	26.24	28.61	20.90	17	2.54
125	18.29	28.60	14.88	14	4.58
150	15.71	20.00	14.10	16	1.89
200	13.71	14.90	12.10	14	0.62
250	12.30	13.50	11.10	11	0.68
300	11.80	12.32	11.54	7	0.29
400	10.94	11.50	10.66	7	0.27
500	10.05	10.50	9.31	7	0.38
600	9.20	9.47	9.06	6	0.15
700	8.42	8.67	8.18	6	0.22
800	7.70	7.98	7.57	5	0.16
900	7.18	7.37	7.01	4	0.18
1000	6.74	7.18	6.42	4	0.36

Source: BPS (Badan Pusat Statistik)

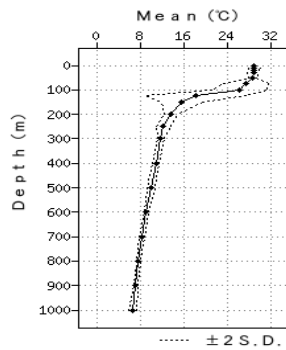


Figure 4. Three location temperature

At western of Siberut island on depth around 600 meter, temperature difference found 20 °C, as good resources for OTEC. Others data at 3 locations can see in Table 3.

Table 3. Data of 3 candidate locations for OTEC plant in West Sumatera

	Location 1	Location 2	Location 3
City/Regency	Pesisir Selatan	Padang	Mentawai Islands
Ordinate	2.10 S /100.51 E	0.57 S /100.21 E	1.26 S /99.8 E
Population (2013)	568.520 people	871.534 people	82.355 people
Electricity & Water	- Pancung Soal city - Balai Tapan city - Baganti city - Ranah Pesiri	Padang city	Siberut Island
Sea surface temperature (°C)			
- January	28.80	28.80	28.80
- July	29.01	29.01	29.01
Depth (m)	600 to 700	600 to 700	600 to 700
Distance from coastline	12 km	18 km	10 km
History of Typhoon	None	None	None
Tsunami	None	None	None
Earthquake	Many	Many	Many

Source : BPS (Badan Pusat Statistik)

4 Conclusion

1. Indonesia is very potentially to build of OTEC Plant, due to differences of sea surface temperature and deep sea water in

approximately 20 °C throughout the waters of the sea.

2. Candidate of OTEC Plant for sites in Indonesia is West Sumatera.: Pesisir Selatan, Padang & Mentawai Island.

References

- [1] Avery, W. H, "Renewable Energy from the Ocean" – a guide to OTEC, Oxford University Press, pp. 280 (1994).
- [2] Achiruddin, D., K.Saito. and G.C. Nihous, "Feasibility Study of OTEC Plants in Indonesia", Trans. Of the West Japan Soc of Naval Architects, No. 94, August 1997.
- [3] Achiruddin, D., Ikegami, Y, "Possibility Study To Develop OTEC & DOWA In Indonesia", 2010.
- [4] BPS, "Sumatera Barat (West Sumatera) Dalam Angka", 2014.
- [5] Ikegami, Y., and H. Uehara, "Performance Analysis of OTEC Plants at Off design Coditions: Ammonia as Working Fluid", Solar Engineering, 1, pp. 633-638, 1992.
- [6] Website Wikipedia, West Sumatera Province, 2014.