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Vannamei Shrimp Cultivation using Discharge Warm Water of 2 MW OTEC in Siberut, Sumatra Barat, Indonesia

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ABSTRACT

Indonesia is an equatorial country located at latitudes less than 20 degrees covered by 77 % ocean with thousand islands, strain and many difference of topography. Most of areas are in the deep sea, OTEC is very compatible build in Indonesian. As OTEC releases a large amount of warm sea water after evaporating ammonia to rotate the turbine, the discharge warm water may be used for shrimp cultivation. This paper discussed on potential of discharge warm water of 2MW of closed cycle of OTEC for Cultivating Vannamei Shrimp in Siberut Island, Sumatera Barat-Indonesia. It was founded that the Siberut Island has potential OTEC due to the gradient temperature more than 20 °C which can produce electricity and fresh water. The discharge warm water from 2MW OTEC is potential to irrigate 1.01 km^2 of extensive, 0.459 km^2 of semi intensive and 0.389 of intensive shrimp farms.

KEY WORDS: *Siberut Island, Sumatera Barat, Indonesia, Ocean Thermal Conversion Energy, Shrimp Cultivators.*

NOMENCLATURE

FAO	Food and Agriculture Organization
FCR	Feed Conversion Ratio
ITC	International Trade Center
LMTD	Long Mean Temperature Difference
OTEC	Ocean Thermal Energy Conversion
PLN	Perusahan Listrik Negara
SST	Sea Surface Temperature

1.0 INTRODUCTION

Indonesia is a tropical archipelago consisting of 17,000 islands with coastline of 95,185 kilometers has the potential to make more than 3 million hectares of shrimp farms. Indonesia has the potential of coastal land for the largest shrimp farms in the world [1]. Data based on Food and Agriculture Organization (FAO) aquaculture production statistics in 2018 stated that Indonesian shrimp production reached 637,555 tonnes in 2016. In 2016 India was recorded as the country that has the highest value of shrimp exports in the world, which reached US $ 3.70 billion. Followed by Vietnam, Ecuador, China, Thailand, and Indonesia with an export value of US $ 2.71 billion each; US $ 2.60 billion; US $ 2.16 billion; US $ 1.98 billion; and US $ 1.67 billion.

Data from the International Trade Center in 2017 [2], the growth of Indonesia's fishery commodity exports in the 2012-2016 periods grew by only 2.37% per year. The total value of fisheries commodity exports in 2012 reached US $ 3.59 billion and in 2016 it increased to US $ 3.86 billion. The contribution of the export value of frozen vanamei shrimp to the total value of fishery exports in 2016 was more than 27%. Shrimp farming can contribute significantly to economic growth and absorb a lot of labor. Thus, shrimp has a large role in the performance of Indonesia's fisheries economy. Currently, large players like CP Prima, BMI, and Sekar Bumi dominate approximately 91% of the export markets in terms of volume of shrimp to US, Japan, and the Europe Union.

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The cultivation activities in shrimp farms are a process production that requires control and success will depend on technical and non-technical factors. As shrimp farming requires very much water, a good water irrigation system is one of the factors needed in determining the success of shrimp farming. Therefore, the engineering of water irrigation is very closely related with various factors which are chain of production processes cultivation business from the beginning to the harvest. Black tiger shrimp is very vulnerable to diseases and viruses that can cause death. 1.5 months can be dead. Compared to vannamei shrimp, the age of 110 days is size 30 cm. the harvest period applies to the age of shrimp between 3 months to 4 months.

As OTEC releases a large amount of warm sea water after evaporating ammonia to rotate the turbine, the discharge warm water may be used for shrimp cultivation. This paper discusses on Shrimp Cultivators using Warm Water Discharge of 2 MW OTEC in Siberut, West Sumatra, Indonesia.

2.0 OTEC IN MENTAWAI ISLAND, SUMATERA BARAT, INDONESIA

2.1 Potential OTEC in Indonesia

Indonesia is the tropical oceans country, approximately located at latitudes less than 20 degrees, may be defined as enormous passive solar collectors. Indonesia has 77% of the total area covered by the ocean, most area in the deep sea as shown in Figure 6. OTEC can be effectively applied within a large scale to provide a source of renewable energy that is needed to cover a wide range of energy issues. J.Koto has applied closed cycle OTEC in several locations in Indonesia 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) [3-13].

2.2 Electricity and Clean Water Crisis at 3T Region

Isolated islands or outermost islands have a variety of specific natural resources, limited, as well as the environmental carrying capacity is limited. In small or outermost islands, both in the West and the East, 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 as shown in Figure 2. 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.

2.3 Overview of Mentawai Island

The Mentawai Islands are 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 [4-8]. 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. Other major islands are Sipura, North Pagai and South Pagai.

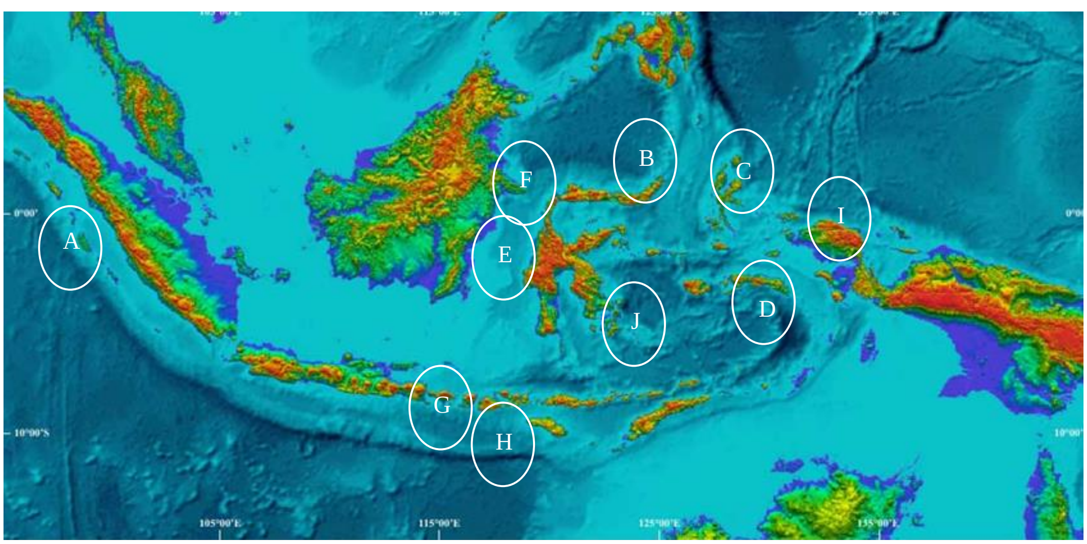

Figure 1: Bathymetry map of Indonesia [1-11]

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Figure 2: Scarcity of clean water (top) and electricity (bottom) in remote islands or outermost in Indonesia.

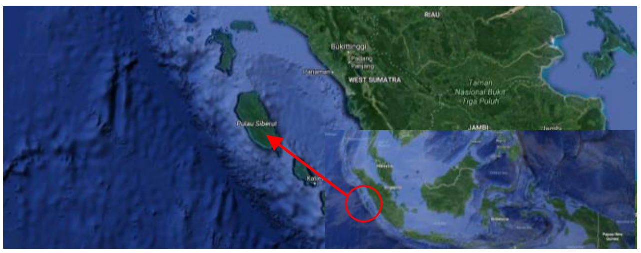

Figure 3: Schematic of the OTEC potential in Siberut Island, Sumatera Barat-Indonesia.

2.4 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 °C before down to the minimum at 28 °C. The average SST is at 29.8 °C.

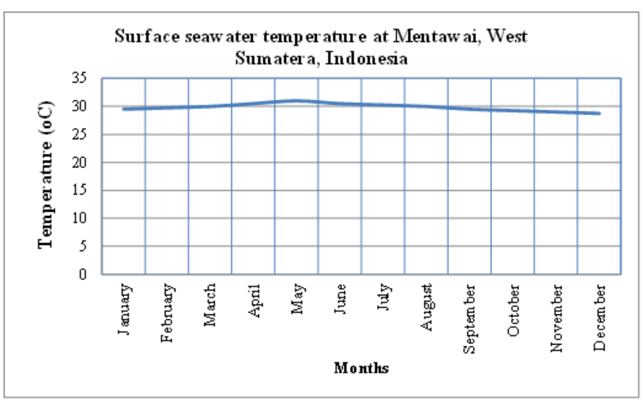

Figure 4: Mean monthly surface seawater temperature in Mentawai Islands, Sumatera Barat-Indonesia.

2.5 Seawater Profile Temperature

Figure 5 shows profile temperatures at different water depths in Sumatera Barat retrieved from NOAA. 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.

2.6 OTEC Closed System in Siberut Island

In the study, the performance was simulated using Subsea Pro as shown in the Figure 6. 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

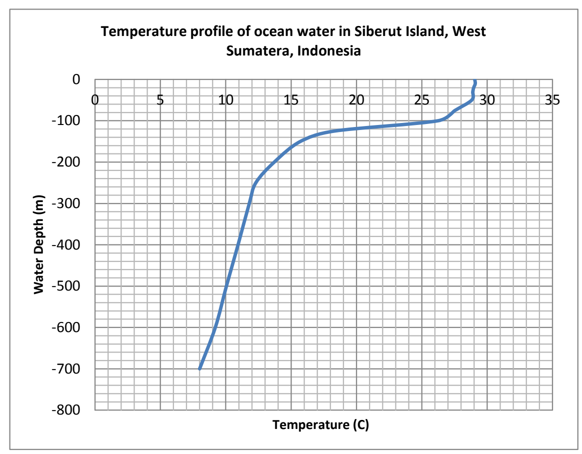

Figure 5: Temperature profile of ocean water in Siberut Island in Sumatera Barat-Indonesia.

Figure 6: Subsea Pro Simulation Software.

Figure 7 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

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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 8 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 OTEC system can produce 7.0 km2 of green-house cooling system
- The system can produce 8730 m3 per day of fresh water for drink after distillation.
- The system can also produce 13000 kg per second seawater which can be used for fish farming.
- The Carnot efficiency of ammonia saturation is 6 percent
  The cycle efficiency of ammonia saturation is 0.41 percent

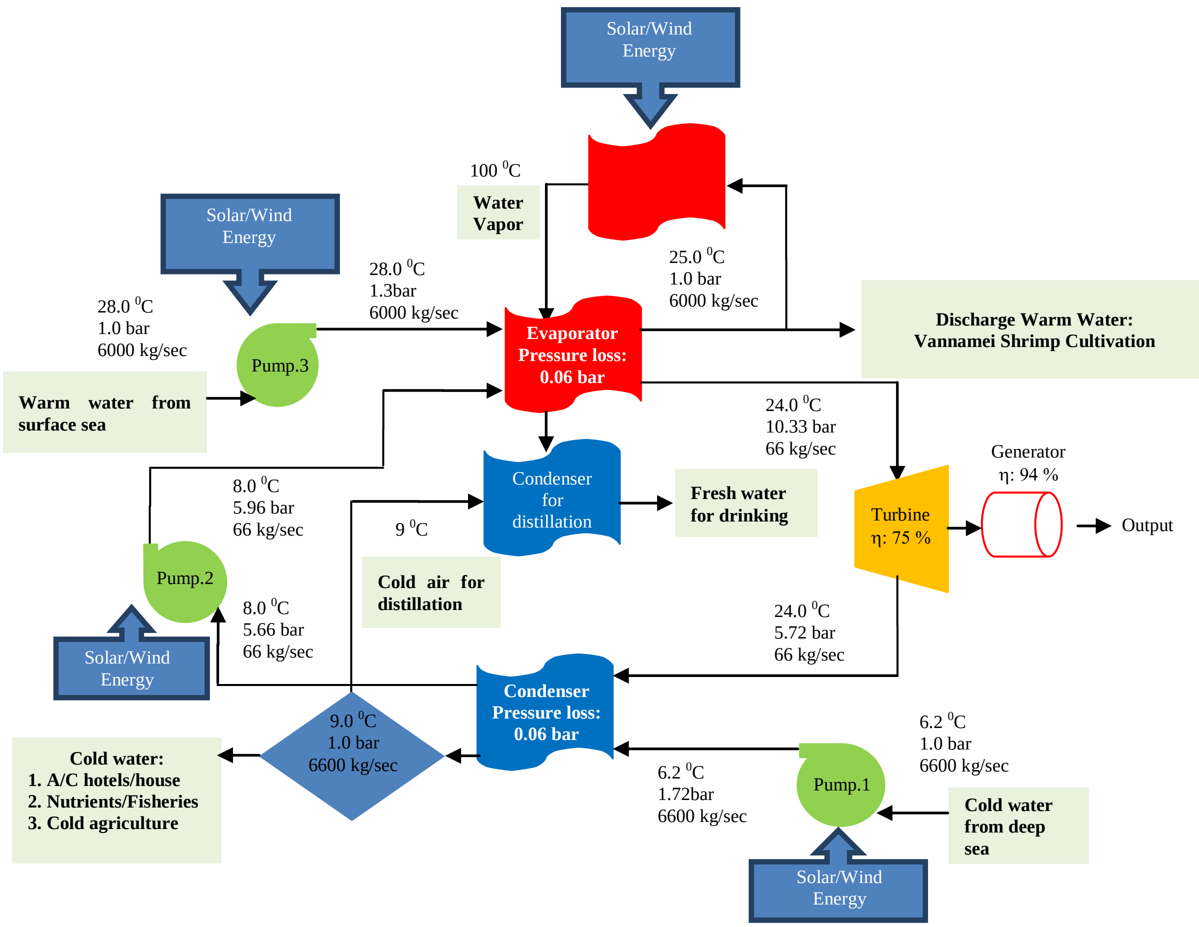

Figure 7: Detailed flow conditions for a single-stage 2 MW plant in Siberut, Sumatera Barat-Indonesia.

OTEC is not only benefit to the needs of the population in the Mentawai islands, Indonesia, but the OTEC can also provide a major economic impact through affordable prices or more cheaper than the price in the field right now. For electricity, the prediction using OTEC in electricity rates remote islands and outermost Indonesia is cheaper than the rate of Perusahan Listrik Negara (PLN) as shown in Figure 9. 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.

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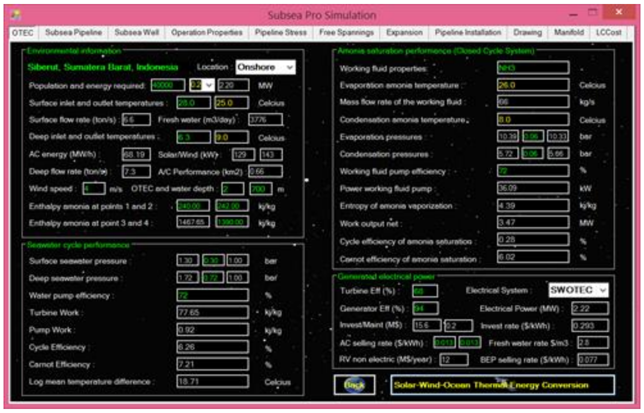

Figure 8: OTEC simulation results in Siberut, Sumatera Barat.

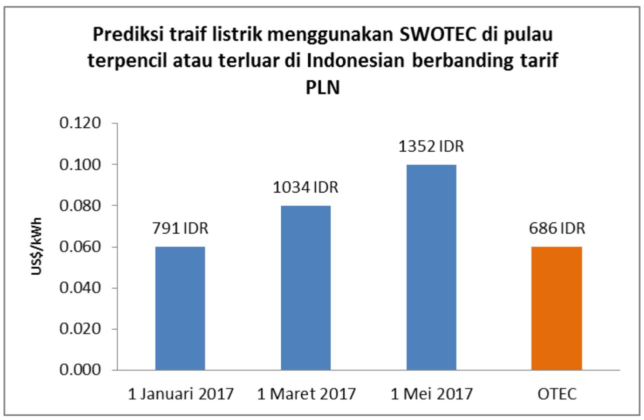

Figure 9: Electricity rate using SWOTEC compared with rate of Perusahan Listrin Negara (PLN) in Siberut, Sumatera Barat, Indonesia.

3.0 VANNAMEI SHRIMP CULTIVATION

3.1 Water Quality

Vannamei shrimp is called Litopenaeus Vannamei which is originally from the West Pacific Coast of Latin America. The Litopenaeus Vannamei in the early days of entering Indonesia was mostly issued by Nicaragua and Mexico. Vannamei shrimp is growing rapidly in Indonesia recently [15-20].

Vannamei shrimp has many advantages over other types of shrimp. The superiority of vannamei shrimp is that it is more resistant to disease, faster growth, shorter maintenance period, high durability during maintenance, relatively easier feeding, Feed Conversion Ratio (FCR) value is low, so farmers are economical in spending on feed. Seed of Vannamei shrimp can survive up to 90 percent and compared to tiger prawns is relatively erratic production rate plus susceptibility to disease. Because of these advantages, the cultivation of Vannamei Shrimp is a profitable type of shrimp.

This is the nature and behavior of vannamei shrimp that need to be known so that farmers can take care and maintain well.

- The optimal water temperature in shrimp farming is 23 - 30 °C. At low temperatures shrimp metabolism becomes low and significantly affects the appetite of declining shrimp.
- Salinity is related to the level of shrimp osmoregulation. The optimal range of salinity for growth and survival vannamei shrimp is 33-40 ppt. In the cultivation of vannamei shrimp, daily salinity fluctuations may not be more than 5 ppt. If the salinity is outside the optimum range, the growth of shrimp becomes slow due to the disruption of the metabolic process due to energy which is more commonly used for the osmoregulation process.

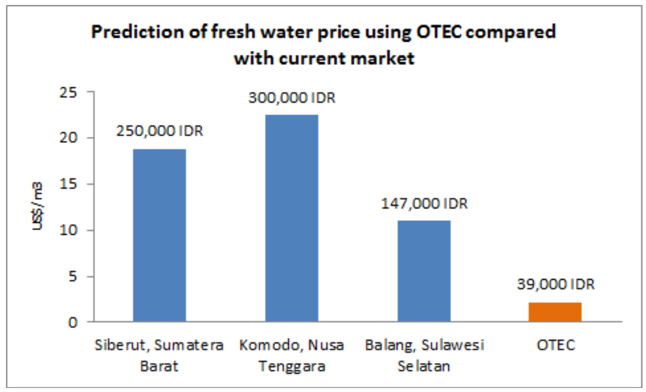

Figure.10: Fresh water price using OTEC compared with current market.

- To be able to live and grow well, aquatic organisms (fish and shrimp) need a medium with a pH range between 6.8 - 8.5 At pH below 4.5 or above 9.0 shrimp will be easily sick and weak, and appetite decreases even shrimp tend to be porous and mossy.
- Vannamei shrimp is eurythermal which is able to tolerate the wide temperature differences in water.
- Because it is nocturnal, Vannamei actively searches for food at night. During the day, Vannamei rests in the mud or attaches to the substrate of the farm.
- Shrimp are a nation of crustaceans. As a type of nation crustaceans are generally cannibal, like to prey on same-sex. Shrimp cannibalism is also found when molting occurs. When molting on shrimp will release a liquid that contains amino acids, enzymes and organic compounds that smells it stimulates the appetite of shrimp. This evokes the cannibalism of shrimp. Smaller shrimps are prone to being eaten by larger shrimp

3.2 Design of Farm

Fish cultivation is an activity to maintain, grow and breed fish and harvest the results in a controlled environment. Common activities include fish farming, shrimp farming, oyster cultivation and seaweed cultivation or algae. In Indonesia, cultivation waters are carried out through various means. The most common cultivation activities carried out in farm. Based on the technology level, fish mound is categorized into 3 types: extensive, semi intensive and intensive as shown in Table 1.

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Table.1: Design, construction and production of shrimp farms at various technological levels [17-21]]

Variables	Technology Used		
	Extensive	Semi Intensive	Intensive
Area (ha)	1.0 - 2.0	0.5 - 1.0	0.4 - 0.5
Plot shape	Four rectangles Square	four square long	Squares
Basement	Slightly mushy	Hard soil	Hard soil / Sand / Gravel
Channels in the farm	Channel surrounding mound	Middle channel	Flue in the middle
Farm :			
Materials	Soil	Soil	Soil / Wall / Plastic
Slopes	1-1.5 : 1	1-1.5 : 1	Upright-1: 1
Sluice gates (units)	One	Two, separate, exhaust doors on embankment	Two, separate, exhaust doors on middle and on the embankment
Water depth (m)	0.4-0.6	1.0-1.2	1.2-1.5
Production (heads/m^3)	1-50 (0.625 kg/m^2)	50 -100 (1.25 kg/m2)	>100 (2.5 kg/m2)

The extensive farm in general needs a mobile channel for shelter shrimp that is maintained as shown in Figure 11. In general, channels the circumference has a size of 0.3 m and width 3-5 m, depending on the area of the mound.

On semi-intensive mound, the channel surrounding mound often does not necessary, because the water depth is sufficient. Here the channel is only needed to throw puddles during farm preparation. Therefore that, the width is smaller and not deeper than at simple farm. However, the middle channel with a slope towards the sluice needed at semi-intensive farms as shown in Figure 12.

Likewise at intensive farms that no longer need there is a mobile channel, but disposal is needed middle or central drain as shown in Figure 13. Cultivation of vannamei shrimp intensive systems does require a lot of capital because they have to provide tools such as

1. Center Drain or automatic waste sucker,
2. Automatic feeder or feeder automatically,
3. for oxygen and sea water pumps.

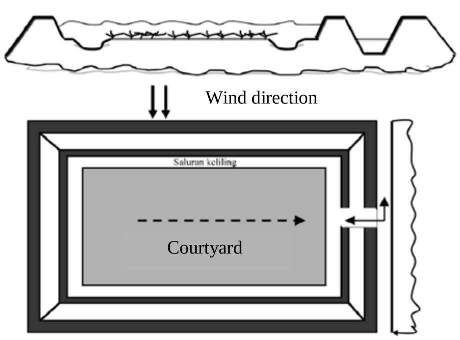

Figure.11: Design of extensive farm from side view (top) and top view (below) from shrimp farms with technology simple [16].

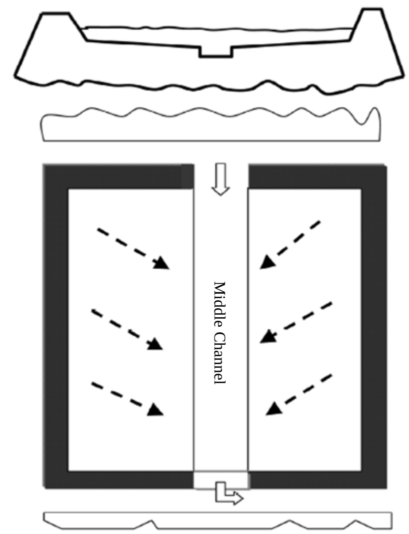

Figure.12: Design of semi intensive farm from side view (top) and top view (bottom) shrimp farms [16].

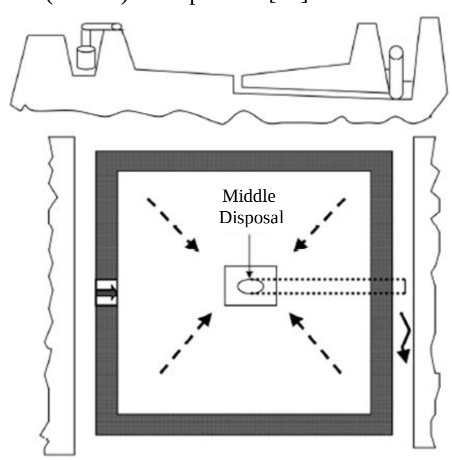

Figure.13: Design of intensive farm from side view (top) and top

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view (bottom) shrimp farms [16].

3.3 Water Requirement

Calculation of water requirements for aquaculture irrigation based on those provided by FAO can be seen in the equation as follows:

$$Q = \frac{a.h}{t.\frac{1-\%lost}{100}} \qquad (1)$$

Where: Q is debit requirement (m^3/s), t is Time needed to fill farms (seconds), h is height for operation (m) and a = farm area (m^2).

Volume of sea water produced in meter cubic (m^3) by OTEC system per day is calculated below

$$V = 13 * 24 * 3600 = 1123200$$

Debit discharge is 10% of farm volume [Andrew, 2015]. Using Equation 3 and Table.1 and only 50% of the volume used, the OTEC system produces shrimp farms as shown in Table 2.

Table.2: Area of shrimp farms produced by 2MW OTEC in Siberut, Indonesia

Variables	Technology Used		
	Extensive	Semi Intensive	Intensive
Area (m^2)	1,010,880	459,490	388,800

3.4 Operational Cost

In order to determine the impact economy of OTEC, production of shrimp and operational cost were taken from extensive farms at Tambak Udang Desa Dlanggu, Kecamatan Deket Kabupaten Lamongan as basic data. The basic data from the site shows that the operational cost of extensive farm is about IDR 60 million for farms covering an area of 10.000 m^2per year (IDR 6000.0 m^2per year) [22]. The operational costs consist of initial management costs, diesel fuel, shrimp feed and guard operations.

3.4 Production

Vannamei shrimp usually can live around 70 - 90%. Annual production of the extensive farm is 3 times. Each harvest is at least 1.4 tons of maximum harvest is 1.9 tons. The average shrimp harvest per year is 4.95 tons or 0.569 kg per m^2. While cultivation in incentives with feed can produce as much as 9.8 tons per 10.000 m^2. It should be noted that the farm uses windmills for oxygen assistance and also regulates the flow of water so that it does not shut up. 60 * 5,000 seeds were from fries.

Vannamei shrimp can be harvested after entering market size 100 - 30 heads per kg or 10 grams/head - 33 grams/head. WWF (2014) stated that production for extensive or traditional scales is 1-50 heads/m3, semi-intensive is 50-100 heads / m3 and intensive is 100 and above. There are two ways to harvest shrimp, which is done in part or in total harvest. Partial harvesting is done in the morning to avoid shrimp molting and low DO. First, shrimp are harvested as much as 20-30% of the total shrimp. Then partial harvest in sizes 80 to 60 shrimps per kg. The total harvest is usually when the shrimp has reached size 40 head per kg. The total harvest is carried out using net bags that are installed at the sluice gate then followed by pulling nets. The remaining shrimp can be taken by hand. Dry water for total harvest is done quickly to avoid harvesting shrimp molting for a maximum of 3 hours, more than that shrimp will be stressed.

Using data in Table 2, 2MW OTEC system will produce 575.1 tons of shrimp per year for extensive farm. It is assumed that world shrimp prices remain in the range of US$ 6 per kg due to production is still unable to catch up with demand. Therefore, the economic impact of the OTEC is US$ 3.4 million.

5.0 CONCLUSION

In conclusion, this paper discussed potential of discharge warm water of 2MW OTEC for Shrimp Cultivators in Siberut, Sumatera Barat, Indonesia. The results founded that Siberut island, Sumatera Barat, Indonesia has gradient temperature more than 20 0C. 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 OTEC system irrigates water for 1.01 km2 of extensive shrimp farm, 0.459 km2 of semi intensive shrimp farms and 0.389 of intensive shrimp farm. The economic impact generated from shrimp farm is US$ 3.4 million.

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