Promotion of Least Cost Renewables in Indonesia (LCORE-Indo)

Assessment of Photovoltaic Application on 10 GT Fishing Vessel

A pre-feasibility Study

Compiled by:

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February 2014

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Promotion of Least Cost Renewables in Indonesia (LCORE-INDO)

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Chapter 1
Introduction

1.1 Background

Indonesian geographical location supports the fishery industry in the country. With 2.55 Million km² of exclusive economy zone, Indonesia has one of the biggest marine capture potential in the world.

According to statistic data from Ministry of Marine Affairs and Fisheries (MMAF), there are 589.182 marine fishing vessels operating in Indonesia in 2011. These vessels are mostly traditional in nature, and powered by fossil fuels. For one trip each vessel requires a big amount of diesel fuel from 500 litre up to 17,000 litre (depends on vessel size and trip duration)[1]. These diesel is used not only for running the machine but also to run an auxiliary diesel generator that supply energy for on board activities.

The fuel to produce energy that fishery uses, is important yet underappreciated aspect of its environmental and economic sustainability. While fishermen have always concern with the cost of fuels, the need to look further into the use of fuel on board is important in order to find the best cost-benefit solution for energy generation.

In recent years, there are several studies conducted to search for a solution of fuel in fishery. Yet the conclusion drawn from these studies is that (at least currently), there is no viable fuel alternatives for commercial fishing vessel which straightforwardly solve the problem of high fuel cost and emission intensity (Tyedmers, 2001) (Tyedmers, 2004). However, attempt to reduce the fossil fuel usage in fishery industry, particularly in Indonesia, is still possible with replacing the energy source for activities on board with renewable energy source.

This study is done under the framework of 'Least Cost Renewables in Indonesia (LCORE-INDO) which was initiated by Directorate General for New and Renewable Energy and Energy Conservation (DG-NREEC) and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) in 2012. Aligned with GOI target to reduce oil consumption by 20% in 2025 and increase the use of renewable energy share to 25% (Ministry of Trade, 2006), this report intends to

[1] Data based on Department of Fisheries and Marine Affairs in Tenau port Kupang, November 2013.

explore financially viable solution for marine fishery industry by introducing least cost renewable energy application on fisherman vessel.

1.2 Objectives

The main objective of the report are:

- Provide an overview of energy consumption on 10 GT fisherman;
- Identify the potential of replacement of diesel generator in the vessel by solar application in 10 GT vessel;
- Analyse the technical and financial viability of solar application on 10 GT fisherman vessel.

1.3 Methodologies

LCORE-INDO team has done a site visit study to Kupang, NTT and interviewed ship builder company which produces up to 1000 vessel of various sizes per year, and is on regular basis receive orders from both provincial and central government to build ship for government projects. The latest project that the company received is the development of 13 vessels with 10 GT size from the Marine Affairs and Fishery Industry (MMAF) as part of help given to refugees from Timor Leste. Vessels from government projects are usually given away to group of fishermen to increase their economical status from crewmen to vessel owner. However, fishermen are faced by fluctuated volume of catch fish but increasing operational cost. The potential part will focus on the possibility feasible in the vessel to overcome the challenge. Solar technical system design will be based on current energy demand data, with energy saving measure. Whilts on financial part, the analysis will focus on replacing an on-board diesel generator and saving the diesel fuel cost for operational and maintenance cost.

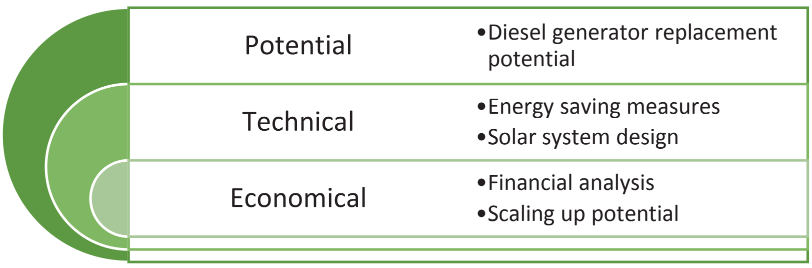

Figure 1 Approach taking in prefeasibility study for solar system application on 10 GT vessel report

Chapter 2

2 Potential of least cost solar application

The finding during site visit is that the energy used for activities on board is produced by an auxiliary diesel generator, separated from the main engine that power the vessel machine. This generator runs independently from the machine generator and mostly used during night time for lighting.

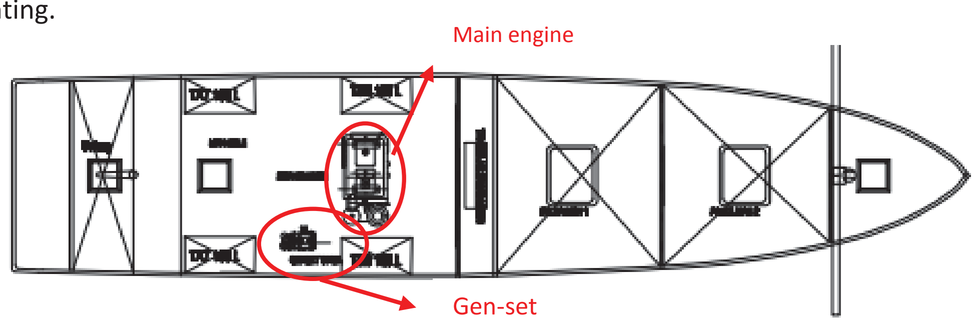

Figure 2 General arrangement of 10 GT fishing vessel produced by PT. Putra Unggul Group

Figure 3 Example of 10 GT Indonesia fishing vessel

Based on the interview with fishermen, every night this auxiliary diesel generator consumes 4 litre of diesel which sums up to 1460 litres per year (assuming that the vessel is operating every night). It is powering lighting, and nagivation system in the vessel. The total daily energy demand supplied by diesel generator is 2.2 kWh/day, from this number we can tell that the diesel generator runs inefficiently as it takes around 2 litres for each kWh produced, so the efficiency of the diesel generator is 5%[2]. This report is focusing on introducing energy saving appliances and replacing the generator by solar application to supply energy demand.

[2] One US gallon of diesel fuel contains 40.7 kWh of thermal energy, or 10 kWh thermal energy in each litres of diesel fuel. (http://www.eia.gov/oiaf/1605/coefficients.html)

Vessel specification:

• Type	: Multi purpose vessel
• Size	: 10 GT
• Fishing gear	: Pole and Line
• Material	: Fiberglass Reinforced Plastic
• Length overall	: 14 m
• Beam	: 3.5 m
• Diesel Engine	: 50 – 60 HP
• Auxilary Diesel Generator set	: 3 kVA
• Crew/operator	: 5 – 10 personnals
• Speed	: 6 knot

Because the solar PV system will replace the auxiliary diesel generator, it is important to also analyse the specification of diesel generator system which previously installed. The detail of Diesel generator and CFL lamps used in current system is explained in

Table ***1***.

Table 1 Specification of diesel generator and CFL Lamp in diesel generator system

Diesel Generator Specification[3]

Max. AC Output	3.2 kVA
Cont. AC Output	3 kVA
DC output (generator &charger)	12 – 8.3 V-A
Phase	Single phase
Fuel tank capacity	13 litres
Operation capacity (one tankful) approx.	9.5 hours
Dry weight	55 kg
Dimensions L x W x H	650 x 496 x 530 mm
Warranty	1 year
Price (approx.)	IDR 4.000.000
Lifespan	3 years

CFL Specification[4]

Price (approx.)	IDR 9.000
Lifespan	2 years
Lamp Wattage	15 Watt
Lamp Voltage	51 V
Lamp Current EM	0.335 A

[3] Based on Yanmar Diesel Generator Model YDG3700N specification. Retrived from http://yanmar.com/product/industrial/catalog/pdf/diesel-gasGenerators/YDG_series.pdf,20th Febaruary 2014.

[4] Data based on Phillips TL 15 Watt

Chapter 3

3 Technical analysis

3.1 Energy saving measures

The first step in designing a solar system is to evaluate the current energy demand and where we can preserve. This will be translated in cost savings during financial analysis. In order to save energy and operational cost, we will subsitute the CFL (compact fluorescent lamp) on the vessel with LED (light-emitting diode) lamps.

LED bulbs provide an optimal light color that is equal to or better than incandescent. LED bulbs are more durable and will not break as easily as incandescent or CFL bulbs. LED is initially more expensive than CFL but can last up to 5 times longer than CFL (U.S Department of Energy, 2013). With CFL, lamps need to be replace every 2 years, whereas LED can be used up to 10 years. LED is also use around 75% less energy than CFL. LED chose to optimize the new system design with more efficient, lower voltage and long-life lamps. Below is the load evaluation on 10 GT vessel for every active day on trip using both CFL and LED. These energy demand is the key figures to determine the size of the system needed to install.

Table 2. Daily energy demand on board

Apparatus	Unit	Operating hours		Load with FL (Watt)	Total Load with FL (Watt)	Energy demand per day		Load with LED (Watt)	Total Load with LED (Watt)	Energy demand per day	
		Min (h)	Max (h)			Min (Wh)	Max (Wh)			Min (Wh)	Max (Wh)
Lighting system											
Cabin light	**6**	8	10	15	90	720	900	5	30	240	300
Anchor light	**1**	8	10	25	25	200	250	5	5	40	50
Stern light	**1**	8	10	25	25	200	250	5	5	40	50
Fore side lamp	**1**	8	10	25	25	200	250	5	5	40	50
Starboard side lamp	**1**	8	10	25	25	200	250	5	5	40	50
Navigation system											
Radio VHF	**1**	10	12	25	25	250	300	25	25	250	300
Total	**10**	**50**	**62**		**215**	**1770**	**2200**		**75**	**650**	**800**

By substituting current fluorescent lamp with LED, we can reduce the daily energy demand of the vessel to 800 Wh/day, or around four times lower like depicted in Figure 4. This number will be used as base number to design the solar system.

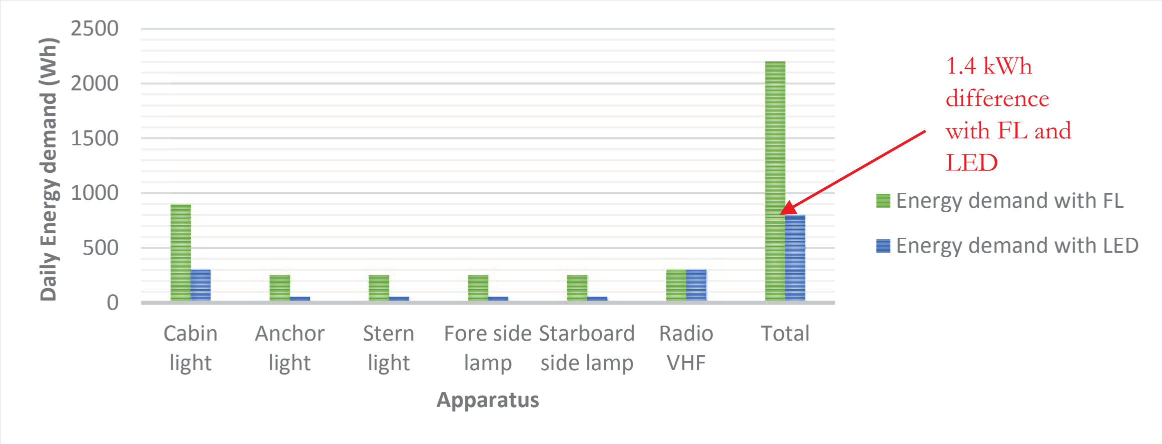

Figure 4 Comparasion of daily energy demand between system with CFL and LED

3.2 Battery Sizing

The solar system will power lighting during the night. Thus, battery becomes a major componet. Oftenly, the fishermen sail for around 5 constitutive days. This trip can be longer or shorter depending on the haul condition. Considering that the system is only used for lighting and navigation purpose, and that weather in Indonesia has mostly sunny days, the system will include only 2 days of autonomy.

For the safety reason, in this study we will use battery loss factor of 85% and 60% depth of discharge and the capacity will be rounded up higher than the actual capacity calculation. Therefore, the size of battery is as follow:

- Typical Nominal battery voltage : 12 V
- Battery loss factor : 0.85[5]
- Depth of discharge factor : 0.6[6]
- Days of autonomy : 2 days

$$Battery\ capacity\ = \frac{power\ output\ required\ x\ days\ of\ autonomy}{nominal\ battery\ voltage\ x\ battery\ loss\ factor\ x\ depth\ of\ discharge}$$

$$= \frac{800\ Wh\ x\ 2}{12\ V\ x\ 0{,}85\ x\ 0{,}6} = 261\ Ah$$

- Battery capacity : ≈ 300 Ah

[5] Based on Sizing off-grid system guidelines of LEONICS Company Limited, a Thai-based Uninterruptible Power Supply (UPS) manufacturer. Retrieved on 28th January 2014. http://www.leonics.com/support/article2_12j/articles2_12j_en.php

[6] Based on Battery Life and Performance, Civic Solar. Retrieved on 28th January 2014. http://www.civicsolar.com/resource/battery-life-and-performance-factors

To design a reliable system, we are going to use two batteries of 12 V, 150 Ah connected in parallel. Type of battery will also play crucial role, therefore, to determine the battery type, desirable characteristics are listed below:

1. High depth of discarge (DOD), which for this system will use 60% DOD at maximum.
2. Long life under cyclic charging and discharging.
3. Easy to transport
4. Low maintenance cost.
5. High charge-discharge efficiency.
6. Reliable for marine application

With above considerations, a deep cycle gel battery because deep cycle battery ensures a quick recovery during use. With this feature, the battery can withstand potentially damaging effects of continual deep discharge and recharge. Gel type is chosen because they are maintenance free, spillproof, submersble, leakproof, and handle the highest of lifetime charging cycles.

3.3 Module Sizing

In Indonesia, the annual average solar irradiation is 5.25 kWh/m^2/day [7], the lowest peak sun hours is in February. Because the vessel operates every month for the whole year, even during less fish season, we will use the lowest peak sun hours as design base. The lowest peak sun hours in Indonesia is 5 peak sun hours[8].

In addition, in order to design a realiable system, inherent efficiency loss factor of a system should be taken into account. The inherent loss factor of a system typically contains of manufacturer's power tolerance (1%), Temperature loss (10%), Dirt (5%), Wiring losses (4%) which sum up to 20% (Peacock, 2012).

$$Power\ output\ required\ = \frac{Wh}{PSH} = \frac{800\ W}{5\ PSH} = 160\ Wx\ 120\%\ \approx 200\ \mathrm{W}$$

Primary function of PV module is providing energy to recharge the battery until it is ready (100 % State of Charge) to electrify the loads. In this study, two modules of 100 Wp monocrystalline modules will be used. There are also other considerations in choosing the modules as followings.

1. High efficiency compared to the low space available. In this case, Thin film module is better for the high temperature environment, high difused irradiation, but it requires

[7] Rumbayan, M., Abudureyimu, A., & Nagasaka, K. (2012). Mapping of solar energy potential in Indonesia using artificial neural network and geographical information system. *Renewable and Sustainable Energy Reviews 16* , 1437– 1449.

[8] This data is based on 22 years average Peak Sun Hours in Kupang, East Nusa Tenggara. Data retrieved from The National Aeronautics and Space Administration website

more space. Monocrystalline is better for the efficiency, and requires the least space, but it is very sensitive to the shade and orientation. Polycrystalline is less sensitive to orientation because it consists of crystal grids with different orientations. Polycrystalline is the best suited module for solar system in vessel. However, due to limited data from Indonesia manufacturer received, monocrystalline silicon module is used.

2. Aggressive substances such as salt or salt-water, or any other type of corrosive agent, could affect the safety and/or performance of the PV modules. Thus, in modules chosen should be ones which withstand the environment in coastal settings. One of the Salt Mist Corrotion Test is International Electrotechnical Commision number 61701 (**IEC-61701**).
3. The tilt angle should be minized to avoid excessive wind load in the open sea and for self cleaning purpose.

3.4 Charge Controller

To prevent over-charging and over-discharging of the battery, charge controller is needed to control the flow of the current and voltage. Charge controller must be rated for the correct current (Imax from the PV array) and voltage and have to suitable with the chosen battery type. Charge controller act as a big switch that either can disconnect or dump the power from PV array when battery voltage is too high. Considering the weather and climate situation in Indonesia where the daily temperature can goes up really high, the charge controller has to have a temprature compensation and has to be fully encapsulated.

Another aspect of charge controller is the effectiveness of sealing against intrusion from foreign bodies. Sealing effectiveness is defined as IP rating (Ingress Protection) which is regulated under International Standard EN 60529 (British BS EN 60529:1992, European IEC 60509:1989). The best application for on board marine charge controller is IP66. The first digit shows the intrusion protection, rating 6 means it will be totally dust tight. The later digit shows moisture protection, and the rating shows protection againts string waters jets and waves.

3.5 Framing

Another consideration in the design is frame. As the system will be used in high corrosive environment, the frame shall be anodized to a thickness and specification suitable for the location and duty of the system. Bolts and nuts used in the system should also be anti-corrosion. In this design, aluminium components are chosen. Alumunium may experience some pitting corrusion but the rate of pitting will diminish rapidly with time with a minimal loss of section and no significant effect on the intigrity of the structure.

To protect againts galvanic corrosion, corrosion protection such as isolation is also needed in the framing. The maintenance of this framing is only consists of regular roof maintenance (e.g. every two year) and washed down with fresh water regularly to minimize the salt deposition in crevices and at contact interfaces.

3.6 System Design

Based on above analysis, we are designing the off grid system with components that fit the requirements. In order to design cost-efficient system and to benefit the local market, we are using components from Indonesian manufacturer as listed in
Table ***3***. This is also to ease the flow of supply chain. An established supply chain infrastructure is needed to make sure that the implementation of solar application is well welcomed by targeted fishery community. Spare part availability and easy maintenance process are important aspects, spare parts have to be easily found in the operational area of the vessel and maintenance process have to be easy for fishermen to be able to do it themselves.

Table 3 List of components in off grid system for 10 GT vessel

Components	Unit	Specification
PV module	2	Monocrystalline 100 W
Battery	2	12 V, 150 Ah
Charge controller	1	12 V, 20 A Autowork
LED lamps	10	5 W
Radio VHF	1	25 W

The system will be mounted on the rooftop utilizing the available space on it, with total area of 4.5 x 2 meters, panel will be mounted in the back area of the roof to make it as far as possible from the engine, to prevent heat coming from the engine. The flagpole which is previously installed on the rooftop will be moved to the back to prevent shading.

The optimal angle varies throughout the year, depending on the seasons and your location and this calculator shows the difference in sun height on a month-by-month basis. For even more precise angling, a tracking system is required. Installing a tracking system will increase the price and make the whole system too expensive. Other consideration is the installation location. During fishing activities, waves will automatically change the angle of vessel’s horizontal surface.

Thus, setting a tracking system is not viable. Instead, the module will be mounted 10° from horizontal surface to make it self-cleaning. A simple illustration of the system and how the solar modules will be mounted in the roof of the vessel are depicted in Figure 5.

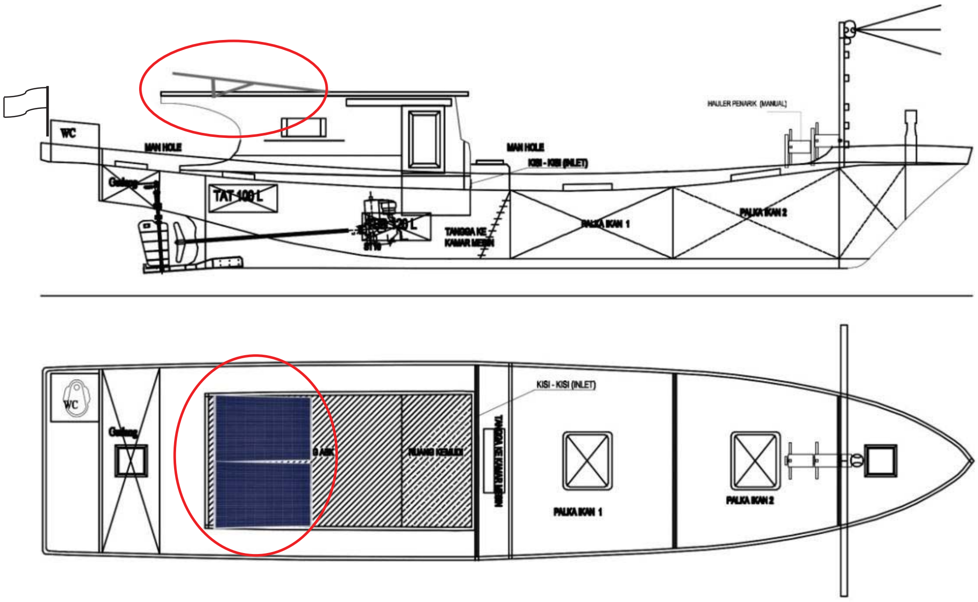

Figure 5 Design of 10 GT vessel equipped with front-facing solar module

Chapter 3

4 Financial analysis

As a result from world oil price rise, the government also increases the diesel fuel price in Indonesia. In the last ten years, the price has risen 300% from IDR 1650 in 2003 to IDR 5500 in 2013 (Pertamina, 2013) with typical increase of 15% every year, subsequently the operational cost for vessel also increases. Operational costs for small scale fishing vessel is counted for more than 70% [9] of vessel's operational expenditures as depicted in Table 4.

Table 4 Expenditures of fisherman 10 GT vessel (MMAF,2014)

No.	Expenditures	Requirements per trip	Price per unit (IDR)	Cost per night (IDR)	Cost per night (USD)[10]
1	Diesel fuel for engine	1000 litres	5,500	5,500,000	466
2	Diesel fuel for diesel generator	20 litres[11]	5,500	110,000	9
3	Kerosene	10 litres[12]	24,000	240,000	20
4	Ice	18 kg[13]	10,000	180,000	15
5	Fresh water	320 litres	500	160,000	
6	Fishermen food supplies	Food for 5 people	20,000	100,000	
TOTAL				**6,290,000**	

Replacing diesel generator suggests that fishermen save IDR 110,000 per trip (refer to Table 4). Although this number seems low compares to the whole expenditures for diesel fuel (2% of total fuel expenditures), this number will sum up to a considerable amount by five years of usage.

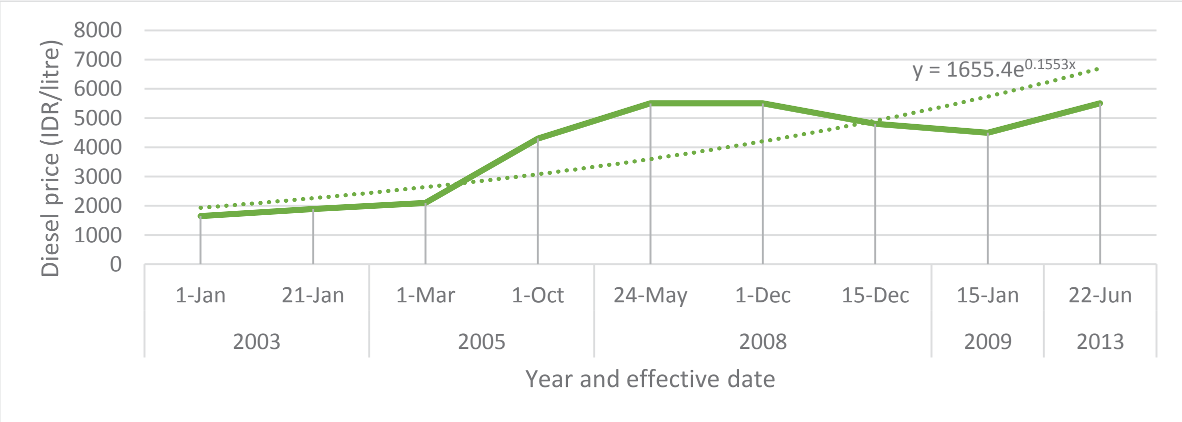

Figure 6 Diesel price increment in Indonesia from 2003 to 2013 (Pertamina, 2013)

[9] Based on Inka Mina project average production cost (MMAF,2014)
[10] Exchange rate is based on Bank Central Asia (BCA) e-Rate on 19th February 2014, 11:33 AM
[11] With assumption that vessel operates for 5 days – this assumption is based on analysis of average operation time of 10 GT vessel by MMAF
[12] Based on the analysis of kerosene requirement per each vessel by MMAF in Inka Mina project
[13] Based on data of average amount of ice brought to vessel size 10 – 20 GT in 2013 in Tenau Kupang port

One of the hindrance in PV application is the high initial investment cost. However, considering that the lifespan of the system is longer than the typical electric power supply system in vessel and zero operational cost concept, PV system brings more profit in long term usage. With assumption that the off grid solar system will replace current diesel gen-set system, the components that are already installed and will still be used for the off grid solar system (e.g. radio VHF and cables used will be the same with the ones in previous system) will not be included in the financial calculation.

Table 5 Total investment cost of solar PV system in 10 GT vessel

Components	Unit	Price	Total
PV module[14]	2	@ IDR 2,860,000	IDR 5,720,000
Battery[15]	2	@ IDR 2,860,000	IDR 5,720,000
Charge controller[16]	1	IDR 455,000	IDR 455,000
LED lamps[17]	10	@IDR 95,000	IDR 950,000
Total investment for solar off grid system			**IDR 12,845,000**

In current system, CFL lamps needs to be changed every two years, while LED lamps can last to ten years. Diesel generator also needs to be replaced every three years. Whereas in solar system, the only part which needs replacement is battery. Battery in solar system last around two until five years , PV module can last to 20 years. Typical battery does not need any maintenance and the only maintenance needed for module is cleaning on regular basis.

Table 6 Comparison between diesel gen-set and solar system

	Solar system	Diesel Generator
Captital Expenditure (CAPEX)	**First Year**	
Power Supply	IDR 11 ,8 Million	IDR 4 Million
Lighting	IDR 950 Thousands	IDR 90 Thousands
Total	**IDR 12,9 Million**	**IDR 4,1 Million**
Operating Expenses (OPEX)	**Five years usage**	
Fuel	--	✓
Replacement of diesel gen-set	--	✓
Replacement of battery[18]	✓	--

The price of diesel is increasing every year. Based on the exponential factor of diesel price increment history Figure 6, the diesel price increment in Indonesia is 15% . This indicates that

[14] Data based on 120 Wp Solar Panel from AdyaSolar. Data taken from quotation of Adyasolar No. 008/AEP/SPH/II/2012
[15] Data based on , Everexceed Deep Cycle Geel battery12-100 G. Data taken from quotation of Adyasolar No. 008/AEP/SPH/II/2012.
[16] Data based on LS 1024 S, EP Solar charge controller. Data taken from quotation of Adyasolar No. 008/AEP/SPH/II/2012
[17] Data based on Adi Daya Unggul LED Hiled 5 W, E27 cap, Retrieved from Indotrading Indonesia website, 25th February 2014. http://www.indotrading.com/product/p57162.aspx
[18] Assumption of three years usage

every year, the vessel operating cost for fuel is increasing by 15%. With the new system, saving is coming from current operation and maintenance cost. Without taking into account the inflation rate in Indonesia Figure 7 depicted the cash flow for four years of usage when both diesel generator in diesel system and battery in solar system are replaced.

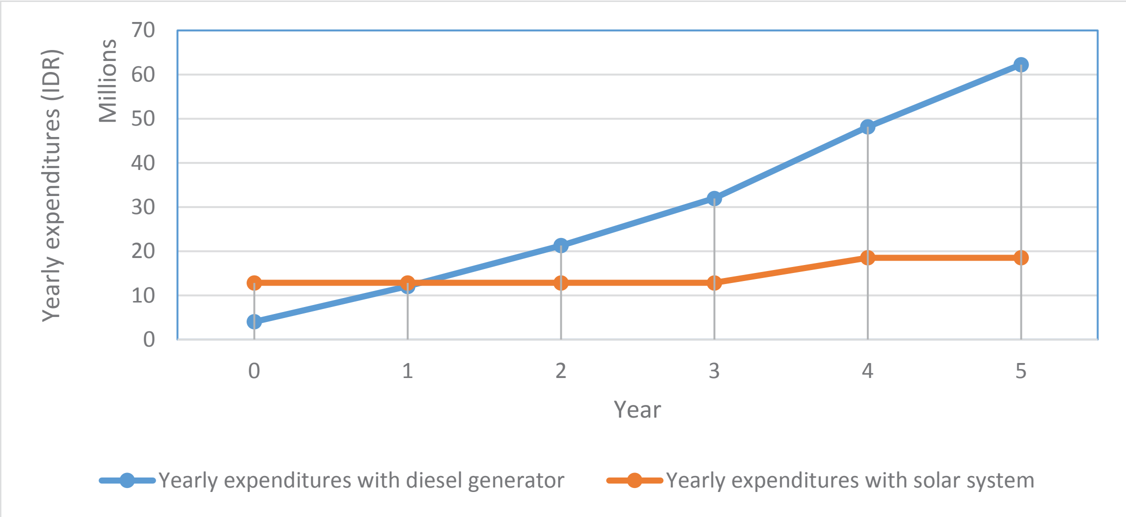

Figure 7 Financial situation comparasion between diesel generator and solar system

In Figure 7 above, we can see that pay back time for solar system is in the first year of usage, thus in the second year vessel owner has recovered all the investment cost for solar sytem installation and start saving from the diesel operational cost. From the graph we can also see that saving is slightly higher in year four than in other years because of diesel generator replacement saving. The accumulated cash flow sums up to 40 Million IDR in year four. The result shows a very promising solar PV application in the off-grid solar fishing vessels.

Installation of green and alternative energy within the marrine and fishery sector e.g. solar PV system, offers positive impacts to various beneficiaries, not only to the government, and fishing community, but also bring a green image to this industry.

Chapter 4

4 Scaling up and CO_2 Reduction Potential

Government of Indonesia (GOI), especially Ministry of Marine Affairs and Fisheries (MMAF) and local government of each provinces, periodically have projects to provide fishermen with fishing vessel. One of the objective is to increase fishermen's status from crewman to vessel owner. Vessel is distributed to group of fishermen with joint ownership scheme and profit sharing system. With solar system in their vessel, these fishermen can save cost for diesel fuel and subsequently gain more revenue.

The reference data in this study is collected from specific 10 GT fishing vessel in Kupang produced by a shipbuilder company. Total production of this shipbuilder company is 1000 vessels per year. Taking data from Chapter 3, replacing diesel generator in these vessels save 26 billion IDR per year. In bigger picture, there are more than 13 thousands vessels of 10 – 20 GT size in Indonesia. If all these vessels change their generator to solar system, it means around 19 Billion litres of diesel fuels per year or IDR 338 Billion saving per year. This can be one of the solution to help 70% of fishermen in Indonesia who still live below the poverty line[19].

Table 7 Scaling up potentials

Number of vessel (unit)	Diesel consumes per year (litre)	Saving from 4 years of usage (IDR)
1	1460	26 Million
500	730,000	13 Billion
1000	1.460.000	26 Billion
13.000	19.980.000	338 Billion

Replacing the auxiliary machine is not only financially attractive, but also helps to reduce environmental concerns such as CO2 emissions. The Food and Agriculture Organization (FAO) State of World Fisheries and Aquaculture Report 2008 states: 'Fisheries and aquaculture make a minor but significant contribution to greenhouse gas emissions during fishing operations and transport, processing and storage of fish,'. In addition, diesel fuel combusion produces toxic substances that are bad for health of the fishermen.

In Table 8, we can see that the potentials of replacing diesel generator in all vessels produced by shipbuilder company in Kupang accounts to 3.8 thousands tons of CO_2 , this number will be

[19] Dahuri, Sapta, & Sitepu (2001). *Pengelolaan Sumberdaya Wilayah Pesisir dan Lautan Secara Terpadu.* Jakarta : Saptodadi

multiplies to 50 thousands tons of CO_2 if we consider the number of 10 – 20 GT fishing vessel in Indonesia[20].

Table 8 CO2 Emission Reduction Potentials

Total vessel use solar PV	Diesel fuel demand	Fuel density	Net Calorific Value	CO2 Emission Factor for Diesel	CO2 Emission Reduction potential
unit	**l/year**	**kg/litre**	**TJ/t**	**tCO2/TJ**	**tCO2/year**
1	1460	0.815	0.043	74	4
500	730,000				1900
1000	1,460,000				3790
13.000	18.980.000				49.270

[20] Total inboard motor fishing vessel size 10 – 20 GT is 13.201 in 2011. (MMAF. (2011). *Marine and Fisheries Statistics.* Jakarta: MMAF)

Chapter 5

5 Conclusion and Recommendation

This study has show that solar PV system is a viable alternative energy source in fishing vessel, although it still cannot cover the energy demand for main machine. It is financially attractive and technically viable. Furthermore, as the global fossil based fuels price is increasing, this substitution helps the small scale fishing vessel to be less vulnarable to fuel price changes. In broader perspective, this replacement will help to alleviate fishermen from poverty by enabling them to gain more revenues.

The reference data in this study is collected from specific 10 GT fishing vessel manufactured in Kupang, and can be a base study for other types of vessel sizes and types. As the size of the vessel increasing, the energy demand will increase simultaneously and from financial and environmental point of view, solar PV system will become more and more attractive.

Annexes

1. Technical Design

a. LED Lamps

File Reference: Adi Daya Unggul Hiled DC Bulb 5W
Distributor : Adi Daya Unggul
LED type : Smd
Socket type : E27
Light output: 450 lumen
Voltage: 12 V

b. PV Module Details

File Reference: Adyasolar
Manufacturer: Adyasolar
Model: SP120 – 12M
Efficiency (STC): 17.96 %
Type of Cell: Monocrystalline
Max.Power (Pm): 100 W
Max. Power Voltage (Vpm): 17.5 V
Max. Power Current (Ipm): 5.72 A
Open Circuit Voltage (Voc): 21.5 V
Frame: Alu Extrude

c. Battery Specification

Considering the unstable condition on the sea, a gel battery with minimum maintenance is chosen. With Thick positive plate design for maximum service float life - 12 year design life @ 20˚C(68˚F).

File Reference: Everexceed Deep Cycle Gel Range
Manufacturer: Everexceed
Battery type: 12 – 150 G
Voltage: 12 V
Max. Charge Voltage: 14.1 V
C20 Capacity: 150 Ah

d. Charge of Controller

Maximum array short circuit current Isc is 12.42, thus a charge controller of 12 V 20 A is chosen. The charge controller will need to have electronic protection functions like overcharge protection, deep discharge protection, automatic electronic fuse, overtemperature and overload protection and overvoltage protection at module input.

Charge circuit voltage drop	: ≤0.26V
Discharge circuit voltage drop	: ≤0.15 V
Self consumption	: ≤6mA
Working temperature	: -35° C to +55° C
Storage temperature	: -35° C to +80° C

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