Transformation of Monohull to Catamaran Hybrid (Diesel-PV) Fishing Vessels to Reduce Exhaust Emissions

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***Abstract*— the fishermen's dependence on fossil fuels is still very high at 95.4% and has not decreased until now. The increased fuel price and reduced fossil fuel availability make fishermen struggle to fish. IMO (International Maritime Organization) noted that around 277 million tonnes of fuel are consumed by ships with fossil fuels. According to an emissions study conducted by IMO, 961 million tonnes of CO_2 accounted for 2.5% of global emissions. This study aims to reduce exhaust emissions by vessels from fossil fuels by making the ship into a hybrid (Diesel-Pv). Making the ship a hybrid with solar panels will save fuel consumption. The method used is the trozzi method approach. The results obtained from changing the configuration to a hybrid can reduce the issued emission by around 57%.**

Keywords— hybrid (Diesel-PV), exhaust emissions, solar panel, fuel consumption, reduce emissions.

I. Introduction

The fishermen's dependence on fossil fuels is still extreme at 95.4% and cannot be reduced now. The rising fuel prices, as well as the availability of fossil fuels, reduced and less number of fishermen's obstacles in carrying out activities going to sea. Their condition worsens when the supply of fuel, an alternative to diesel fuel for marine fuel, is tough to have. This happens because the people in Indonesia mainly depend on their livelihoods by not being separated from fossil fuels [1]

Another problem is increased operational costs while fishing due to the increased fuel price, widely consumed at the Fishing Grounds [2]. The main composition of operational costs that must be issued by the fishing vessel comes from the cost of fuel (BBM) reaches 45% of the total operating costs. The impact of the increase in fuel prices on fisheries, for example, is for the capture fisheries will affect the production cost structure [3]. Not only reduce profit due to the increase in costs but also reduce the frequency of going to sea. The frequency of going to sea is reduced due to the difficulty of accessing fuel, besides necessary to reduce the level of losses due to increased fuel prices [4].

Excessive usage of fuels can create air pollution. Along these lines, the government intends to save fuel now that it is no longer subsidized [5]. Using fuel oil motorized boats is not only uneconomical but also enforcement—approximately more than 20 million motorized ships worldwide and widely. The vessel has dumped more than 472,000 metric tons of gas from burning oil into the atmosphere. In addition, about 236,000 metric tons of oil gas every day is wasted in the sea due to low motor efficiency used on ships [6]. IMO (International Maritime Organization) notes that in 2007 about 277 million tons of fuel were consumed by the ship.

In 2012, 961 million tonnes of CO2 contributed to 2.5% of total world emissions, according to research undertaken by IMO [7]. The International Convention for the Prevention of Pollution from Ships (MARPOL) has pushed nations to reduce cruise ship emissions. Members of the International Maritime Organization (IMO) announced a plan in April 2018 to reduce annual emissions from shipping by at least 50 percent by 2050 compared to 2008 to eliminate emissions by the end of this century [8]. Throughout the past, the International Council for Clean Transportation (ICCT), the International Maritime Organization (IMO), and also other organizations have investigated the technologies and methods required to minimize fuel use aboard vessels to decrease carbon emissions [9]. In approximately 35, 37, and 107 years from 2008, the economic model established by [10] forecasts that oil, gas, and coal would decline, respectively. Also, given the effects of global warming on humans, energy use of renewables is considered an urgent task [11]. The IPCC report [12] shows that the present CO2 content in the atmosphere is 100 ppm greater than pre-industrial levels, or around 34% higher. Therefore, it may be required to replace conventional marine fuels, which are significant contributors to greenhouse gases, with renewable energy sources to achieve greater sustainability.

Several shipyards, ship operators, and ship owners seek strategies to employ greener energy as a maritime fuel source. Solar energy has emerged as the most potential future maritime fuel source [13] since it is well-known that solar energy is significantly cleaner than traditional fossil fuels. Seeing this situation, it is necessary to make a breakthrough to find a solution for fishermen to be separated from the problem and dependence on fossil

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fuels. The current propulsion system is based on optimal power for the designed vessel. However, most ships are in this state within the hour of their daily mission. Thus, diesel engines are frequently overloaded with poor efficiency or excessive emissions [14]. Using an electric propulsion system in a hybrid arrangement with a diesel engine is seen as a method to reduce fuel consumption and exhaust emissions for both new and current existing ships. The advantages of electric propulsion are conversion efficiency, maneuverability, dependability, and safety [15].

In Indonesia, hybrid power production systems (solar cells and diesel generators) offer an alternative to the detrimental impact of traditional power generation methods [16]. The development of shipping technology is quite advanced and indicates the ability to master technology in the marine sector [5].

In the automotive sector [17], hybrid technology, which combines the primary mover with energy storage, has been effectively used in automobiles. The most recent application reduces CO2 emissions [18]. Besides that, depending on the drive parameters, the Hybrid Power system power output and SOC battery significantly affect CO2 emissions [19]. The newest update in the Diesel-electric propulsion system helps achieve material savings for massive fuel but must meet current environmental requirements to meet operational demands [20]. Currently, clean energy ships are becoming one of the hottest topics in the world by replacing fossil fuels which will run out in the not-too-distant future, and climate change are at an alarming rate [13].

The hybrid technology is expected to help the fishermen overcome existing problems. In terms of the cost of using fuel, it can be reduced by using solar PV so that with limited fuel used, the ship can still sail. In terms of the environment, it is expected to reduce pollution due to fossil fuels because some more energy is obtained from batteries supplied by solar energy through solar panels. Various applications for the next hybrid engine are widely used. This application generally refers to the specific optimal design based on innovative research. One of them is using solar panels as an energy source for the hybrid. This study aims to evaluate changes in the configuration of the existing propulsion system to a hybrid (diesel and PV).

II. PROPULSION SYSTEM

A. Existing Propulsion System

The ship data used in this study were ships from the Ministry of Marine Affairs and Fisheries with a size of 30 GT. The existing propulsion is based on a diesel engine connected to a reduction gear that acts as the prime mover. This ship is also equipped with an additional generator to supply electricity. Most situations under which the ship works, such as maneuvering or low-speed navigation, are often accomplished with minimal diesel engine power needs. This operation is far from ideal diesel engine operating, requiring a high specific fuel consumption and increased exhaust gas pollution [21].

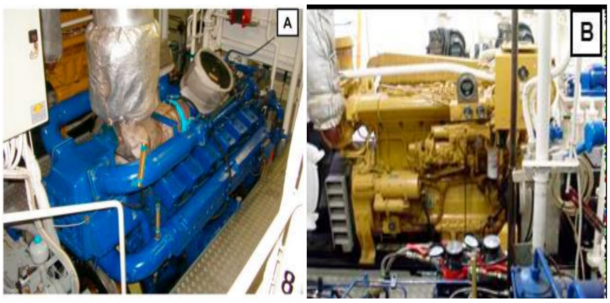

Figure. 1. Diesel engine (A) and Genset (B).

Before the 19th century, ships were driven using oars and sails. Then, they developed a steam engine used for ship propulsion. During the 19th and 20th centuries, ship propulsion evolved from steam engines and steam turbines to diesel engines as they are today [22].

Figure 2 illustrates the types of conventional ship propulsion engines currently available. The prime mover (1), often a diesel engine or gas turbine, can drive the propulsion (3) propeller, either directly or via a gearbox (2). The production and distribution of electrical power for electrical loads (5), such as variable speed drives (4), ventilation heating and air conditioning (HVAC), and other mission-critical and auxiliary systems, requires a separate AC power supply (6). This power network (7) is fueled by diesel, a steam turbine generator, or a gas turbine.

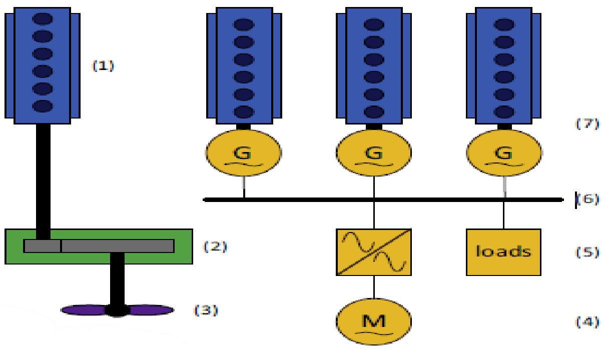

Figure. 2. Typical mechanical propulsion system [23]

B. Hybrid System

The study of ships with diesel-electric propulsion differs from those of conventional propulsion vessels. So, in conventional systems, electricity and drive sources come from two different sources. On the other hand, hybrid electricity sources and propulsion systems are closely related and should be evaluated during the design process, considering techno-economic, pollution, and other factors [24]. Recent developments in the diesel-electric propulsion system are helping the enormous fuel savings generated by diesel engines, but the marine propulsion industry still needs to meet environmental requirements while operating requirements.

The environmental impacts of the many uses of diesel engines are exhaust gases, air pollution, and the greenhouse effect. Exhaust emissions from the combustion of diesel fuel aboard are a major cause of air pollution (SOx, NOx, PM, CO, CO2, and HCs). According to a study conducted by the International

Maritime Organization (IMO), the shipping industry's carbon dioxide emissions account for 2.2% of overall emissions [25]. If business continues as usual (no action is taken), Emissions of co2 from large vessels are estimated to increase by 50–250 percent by 2050 [25].

For this reason, the International Maritime Organization's (IMO) Marpol rules put more harsh limitations on ship emissions [26]. Annex VI of the IMO Marpol Convention imposes limitations on the nitrogen oxide (NOx) emission cycle for diesel engines with more than 130 kW outputs. Tier 2 diesel engines on ships developed after January 2011 are restricted to 7.7 grams per kilowatt-hour for high-speed engines and 14.4 grams per kilowatt-hour for extremely low-speed engines. Starting in January 2016, at Tier 3, these limits were reduced to 2.0 g / kWh and 3.4 g / kWh [26]. Once the electric demand for the auxiliary engine is a small percentage of the required propulsion, the conversion losses lead the electric propulsion system to consume more gasoline [15]. Additional electrical equipment adds cost, weight, and dimension [27]. Therefore, low-speed boats may profit from the hybrid propulsion system [28].

Direct mechanical drive (1) delivers high-speed, efficient propulsion in hybrid propulsion. In addition, the electric motor (2), linked to the same shaft via the gearbox (3) or directly to the propeller's shaft, offers low-speed propulsion, preventing wasteful operation of the main engine under certain loads. This engine may also function as a generator for electrical loads aboard ships that provide power network services (4). Figure 3 depicts a typical hybrid propulsion system configuration.

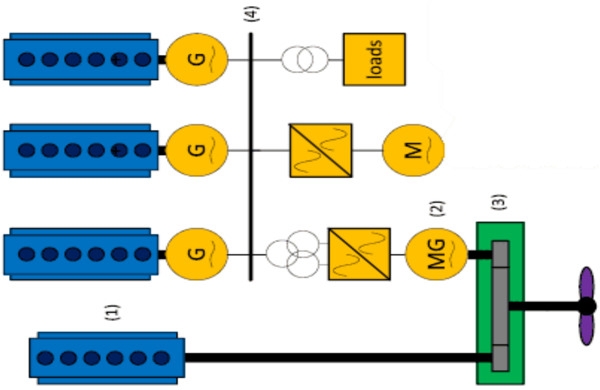

Figure 3. Typical hybrid propulsion system [23]

When the mechanical drive engine is operational, this method permits either an electric generator or the generator to provide generating capacity. Generating capacity is often determined by rule-based or operator-based restrictions.

C. Solar Panel Applications

The maritime sector is also attracted to solar energy. To replace traditional propulsion technologies that continue to use fossil fuels. Research [29] has revealed the advantages of diesel-powered and hybrid boat battery boards that can be charged from a cleaner energy source. Research [29] consistently found the benefits of using batteries to reduce CO2. Apart from using batteries, he also focuses on researching the application of renewable energy systems on ships. Crystal and thin-film solar systems are contrasted with other renewable energy methods (wind, tides, and wave energy). Their results show that the thin layer of the solar system will become more economical than a crystal [30]. As a result of substantial advances in solar energy, solar power has become a cost-effective alternative to petroleum for pleasure boats, boats, ferries, and tour boats.

In contrast, large vessels save fuel by utilizing solar electricity, which is quite tiny compared to small vessels. In light of these discoveries, academics and technology developers now concentrate on hybrid systems to improve fuel efficiency. In the 1990s, the United States gained patents for combining wind and sun energy. However, different ideas and concepts for hybrid systems began to develop before the 1990s until recently; no large commercial ships are operating.

Newman and Schaffrin team began to develop a solar energy conversion system [31,32]. Diab et al. [33] explored the advantages of a hybrid system for use on land and ships that combines a diesel engine with a battery pack and solar panels. Applying solar panels and battery systems to a ship will minimize greenhouse gas emissions by around 10,000 tonnes during a normal 25-year vessel lifetime. When integrating solar panel systems and battery packs on ships, their key concern is the environmental effect assessment conducted during the operating phase.

Some study has also concentrated on energy storage systems to determine how they may assist solar panel systems in reducing fuel consumption and emissions over the ship's service life [34]. Yu [35] assesses energy efficiency and pollution reduction using a hybrid solar panel system, battery packs, and diesel generator. The findings demonstrated that hybrid systems might fulfill local emission reduction criteria and provide advantages at the ship's end of life. Kannan et al.[36] compared the efficiency of a PV system to that of an oil steam turbine system. According to research, photovoltaic systems are excellent for lowering greenhouse gas emissions.

III. METHODOLOGY

A. Solar Panel

1) Energy Resources

The overall energy demand (Eload) is comprised of the energy necessary for propulsion (Eprop) and the energy needed for service-related electrical equipment (Eserv). The propulsion energy is a function of the propulsion power and the amount of the ship's voyage, while the services energy is the power product of electrical equipment and the duration of usage for each piece of equipment. In this instance, the entire ship energy requirement is denoted by the equation Eq (1).

$$E_{load}(t) = \int_0^t P_{prop}(t) . dt + E_{serv}(t); \quad t = 0,1,2, \dots 24 \quad (1)$$

2) PV Energy

PV energy is defined as solar energy harvested by the PV module represented by Eq. (2)

$$E_{PV}(t) = \frac{P_{PV}}{1000} \cdot \eta_s \cdot \eta_c \cdot x_1 \int_0^1 \frac{I_{rr}(t)}{G_{STC}} dt; \quad t = 0,1,2 \ldots 24 \qquad (2)$$

Where PPV is the peak wattage in watts of the PV module, Irr is the solar radiation in kW/ m^2, and GSTC is the radiation under normal test circumstances equal to 1 kW / m^2. η_s Represents the PV system's efficiency, corresponding to the energy loss caused by converters, wires, temperature, etc. η_c is the charging efficiency, which refers to the power loss that occurs while charging PV energy to the battery, and x1 is the amount of Pv panels to be adjusted.

3) Battery Energy

Equation computes the battery energy (3) Other elements that impact battery capacity, such as temperature, charging current, and discharging, are not considered.

$$E_{batt} = \frac{V_{batt} \cdot C_{batt} \cdot x_2}{1000 \cdot \eta_d} \qquad (3)$$

Where Vbatt is the nominal battery voltage in volts and Cbatt is the battery capacity in Ampere-hours, η_d is the battery discharge efficiency representing the energy loss during the energy discharge process, and X2 is the number of batteries to be optimized.

B. Emissions Calculations

According to the Emission Inventory Guidebook Group 8 [37], the definition of emissions The exhaust gases in the Marine world are all residual emissions that come from:

- Marine diesel engines are used as the primary propulsion or auxiliary engines.;
- Gas turbines are used in boilers for steam turbine propulsion systems.

Of all the power units used for industry marine transportation, Marine Diesel Engine is the prime mover dominant for propulsion and auxiliary power generation. The exhaust gas emissions in Marine Diesel contain Nitrogen, Oxygen, Carbon Dioxide Water Vapor and sulfur. Apart from this, Hydrocarbons and Particulate Materials, Metals, and Organic Micropollutants cannot be reused.

The method to be used for analyzing fishing vessel emission estimates This was done in research conducted by Carlo Trozzi and Rita Vaccaro [38] in his paper entitled: Methodologies For Estimating Water Pollutant Emissions From Ships. The type of pollution analyzed is the pollution obtained due to combustion. The pollution is shown in the Table below.

TABLE 1.
TYPES OF POLLUTANT

Code	Name
Nox	Nitrogen Oxides
SO	Sulfur Oxides
CO	Carbon Monoxide
VOC	Volatile Organic Compounds
PM	Particulate Matter

The calculation of exhaust gas emissions using the Carlo Trozzi formula :

- Fuel Consumption Main Engine
  - Fuel Consumption Main Engine Hotelling (FCMEH):

$$\left(\frac{\textbf{SFOC x Power Engine x Hotteling Time x Load Factor ME hotteling}}{\textbf{1000}}\right) \qquad (4)$$

  - Fuel Consumption Main Engine Maneuvering (FCMEM) :

$$\left(\frac{\textbf{SFOC x Power Engien x Manouvering Time x Load Faktor ME Manouvering}}{\textbf{1000}}\right) \qquad (5)$$

  - Fuel Consumption Main Engine Cruising (FCMEC) :

$$\left(\frac{\textbf{SFOC x Power Engien x Cruising Time x Load Faktor ME Cruising}}{\textbf{1000}}\right) \qquad (6)$$

- Fuel Consumption Auxiliary Engine
  - Fuel Consumption Auxiliary Engine Hotelling (FCAEH) :

$$\left(\frac{\textbf{SFOC x Power Engine x Hotteling Time x Load Faktor ME hotteling}}{\textbf{1000}}\right) \qquad (7)$$

  - Fuel Consumption Auxiliary Engine Maneuvering (FCAEM) :

$$\left(\frac{\textbf{SFOC x Power Engien x Manouvering Time x Load Faktor ME Manouvering}}{\textbf{1000}}\right) \qquad (8)$$

  - Fuel Consumption Auxiliary Engine Cruising (FCAEC):

$$\left(\frac{\textbf{SFOC x Power Engien x Cruising Time x Load Faktor ME Cruising}}{\textbf{1000}}\right) \qquad (9)$$

TABLE 2.
LOAD FACTOR

No	Condition	Load Factor ME	Load Factor AE
1	Hotelling	0,2	0,3
2	Cruising	0,8	0,5
3	Maneuvering	0,2	0,4

Ship emissions are the product of any energy demand from ships and emission factors. The database is adjusted to the emission World. Fuel consumption is already known, and so that it can know the volume and level of exhaust gas emissions.

Emission Calculation:

a. Hotelling =(FCMEH + FCAEH) x Emission Factor (10)
b. Manouvering = (FCMEM + FCAEM) x Emission Factor (11)
c. Cruising = (FCMEC + FCAEC) x Emission Factor (12)

To find the total emission from pollutant is:
Total Emissions = a + b + c (13)
a = Total Emissions of Hotelling
b = Total Emissions of Manouvering
c = Total Emissions of Cruising

TABLE 3.
EMISSION FACTOR FOR MDO (MARINE DIESEL OIL) [39]

No	Pollutant classification	Emision factor (kg/ton)
1	Nox	57
2	Sox	0,7
3	Co	7,4
4	Co2	3170
5	VOC	2,4
6	Pm	1,5

IV. RESULT AND DISCUSSIONS

A. Solar Panel and Battery

Table 4 below is the electrical data for the catamaran fishing boats that have been studied. This data is taken from the Ministry of Marine Affairs and Fisheries of Indonesia.

TABLE 4.
ELECTRICAL DATA

No	Item	Power (W)	Number	Duration of Use (Hour)	Total (Watt Hour)
1	Radio VHF Icom M200	20	1	24	480
2	GPS MAP + Fish Finder Garmin 350 C	300	1	10	3000
3	Navigation room light	20	2	12	480
4	Machine Room Entry Area Lights	20	1	12	240
5	Machine Room Lights	20	4	24	1920
6	Kitchen Room Lights	20	1	5	100
7	Toilet Room Light	20	1	5	100
8	Steering Room Lights	20	1	5	100
9	Anchor Room Lights	20	1	5	100
10	Hatch Room Lights	20	4	5	400
11	Indoor Lighting	20	4	12	960
12	Outer Lights	20	3	12	720
13	Pole Lights	20	1	12	240
14	Red Green Side Light	25	2	12	600
15	Aft Lights	25	1	12	300
16	Anchor Lights	25	1	5	125
17	Warehouse Lights	20	1	5	100
17	Fish Boat Lights (Red & White)	25	2	8	400
18	*Search* Light	500	1	5	2500
19	Spotlights	300	2	5	1200
20	Crew Room Lights	20	1	5	100
21	Pump	350	3	5	5250
		Total			19925

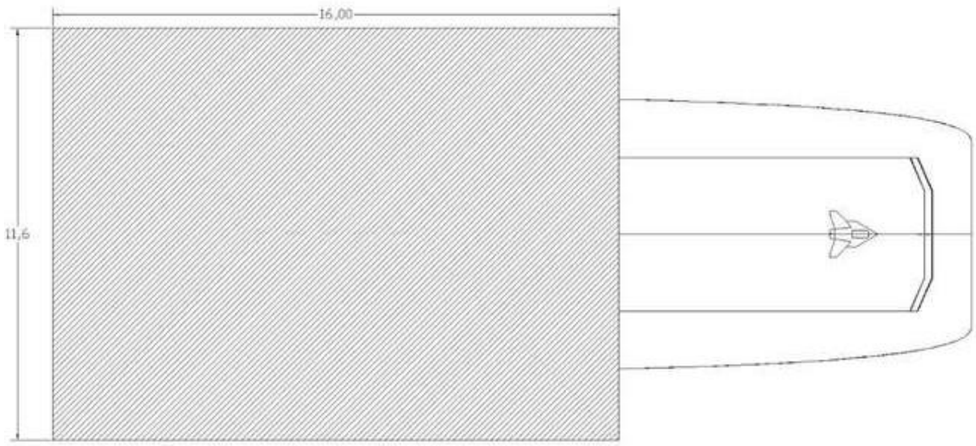

Figure 4. Solar Panel Placement Area

It is assumed that the lights on the ship are already using the type of LED. The duration of use of lamps and other electrical equipment is adjusted according to their function. The total obtained is 19925 watts or 19.93 kW. The total power requirement for this ship is the power for the main propulsion plus the electrical power**.** Table 5 below is the data of the catamaran fishing vessels that are being examined.

TABLE 5.
MAIN DIMENSION ANd POWER

Length Over All (LOA)	24 m
Breadth (B)	7.8 m
Draft (T)	0.97 m
High (H)	2 m
B1	3.54 m
S	5.3 m
Power	56 kW
GT	30

It is evident from the preceding Table that the propulsion power is 56 kW. Even though the sun shines for eight hours in Indonesia (08.00-16.00), the photon beam received from solar panels is only functional for five hours every day. Considering solar panels will supply 5 hours, the power required for the ship is (56 x 19 = 1064 kW). The total power required according to equation 1 is 1064 + 19.93 = 1083.93 kW.

The Figure above is the area used to place the solar panels. The solar panels used are with the specifications in the following Table:

TABLE 6.
SOLAR PANEL SPECIFICATIONS

Max. Power (Pmax)	250 W
Max. Power Voltage (Vmp)	28.9V
Max. Power Current (Imp)	8.7A
Open Circuit Voltage (Voc)	34V
Short Circuit Current (Isc)	9.2A
Weight	16 Kg
Dimension	1480 x 990 x 35 mm

With the area given in Figure 4 (11.6 m x 16 m = 185,6 m^2) and the specifications in table 6, the area of the solar panels = 1.46 m^2, the total area for solar panels is the available area divided by the area of solar panels 185 /1.46 = 126 pieces. The amount of power generated by the 126 solar panels is based on eq (2), where η_s 80% and η_c85% [40] = 128.5 kWh. The amount of battery is based on the weight of the battery and volume, where the total weight of the battery is $\leq$ 3500 kg, and the volume of the battery is $\leq 11 m^3$ according to the capacity of the battery space for battery storage. The number of batteries obtained is 25 batteries with the specifications in the Table below:

TABLE 7.
BATTERY SPECIFICATIONS

Nominal Voltage	**51.8V**
Nominal capacity @ 1C	192Ah
Charge Voltage	57.7V-58.8V
Charge Current	<95A (recommended) / 100A (max continuous)
Discharge Voltage Minimum	41.3V
Discharge Current Max Continuous	200A
Dimensions L x W x H (including terminals)	36.75"x19.75"x4"

Based on eq (3), the energy for the battery is obtained, where η_d 85% [40] is 212 kW. From the above calculations' results, using a hybrid (Diesel-PV) can save about 19.6% of fuel usage for diesel.

B. Emissions Calculation

Figure 5 below shows the Daily Cruise, or the time the ship is sailing, looking for a fish. You can see the stages of expansion from the fishing base to the fishing ground. The fishing base is where the fishermen's initial port is where the boat is, while the fishing ground is a gathering place for fish or a place marked by the fisherman to catch a herd of fish. Each fishing step is divided into 5 stages. Sailing is a voyage from the fishing base to the fishing ground. The setting is the declining stage of the bait. Drifting is the stage where the ship off the engine after dropping the bait. The ship is at rest, just following the ocean currents. Hauling is the baiting stage. After the bait is withdrawn, the last step is to enter the fish caught into the hold and put the bait back.

In one catching process, it is estimated that it takes 39 hours. It could be faster or longer depending on the cruising distance and the number of fish to be caught. The Figure above uses a maximum speed of 9 knots. The speed of the ship can change depending on the captain. The faster the ship, the more wasteful of fuel it is. The captain must adjust the ship's speed so the fuel is not wasteful. The captain must pay attention to when to use his maximum speed because if it is used at full speed, it will result in a fast battery drain. Also, the captain must pay attention to the correct time when charging the battery. For example, during the day, if the ship is drifting, it can charge the battery through the Solar Panels. The point is how to arrange when to use a hybrid so that pollution can be reduced. Figure 5 above shows several hybrid schemes that can be used. The difference is the equipment in the scheme itself. If you look at the scheme, some use 2 electric motors, and one is. Different types of schemes are only a matter of price, and the power output remains the same depending on the amount of power supplied by the battery.

Most importantly, these schemes can reduce dependence on diesel fuel use. Figure 6 below shows SFOC vs Power. SFOC stands for Specific Fuel Oil Consumption. Power is directly proportional to SFOC. The greater the power, the higher the feeding speed, and the greater the SFOC.

SFOC is the amount of fuel used in units of time (gr / kWh or Liter / Hour). To get practical usage, the captain must be able to adjust the ship's speed so that fuel consumption is low. Low fuel consumption is expected to reduce exhaust emissions produced. The ideal minimum speed is 6 knots, and the captain must play when he has to be at full speed and when to be low.

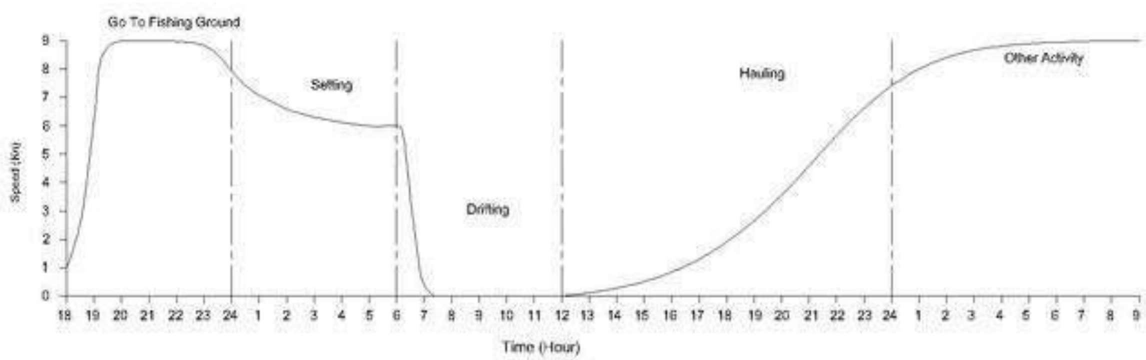

Figure 5. Daily Cruise Ship.

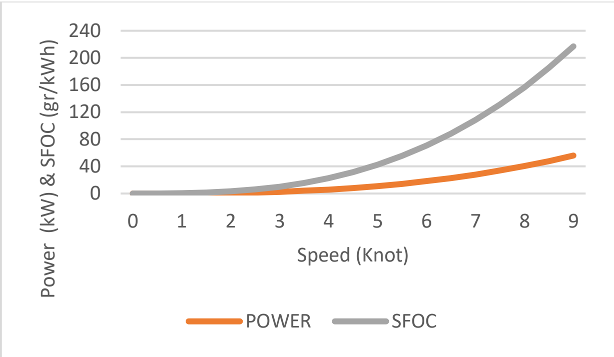

Figure. 6. SFOC Vs Power

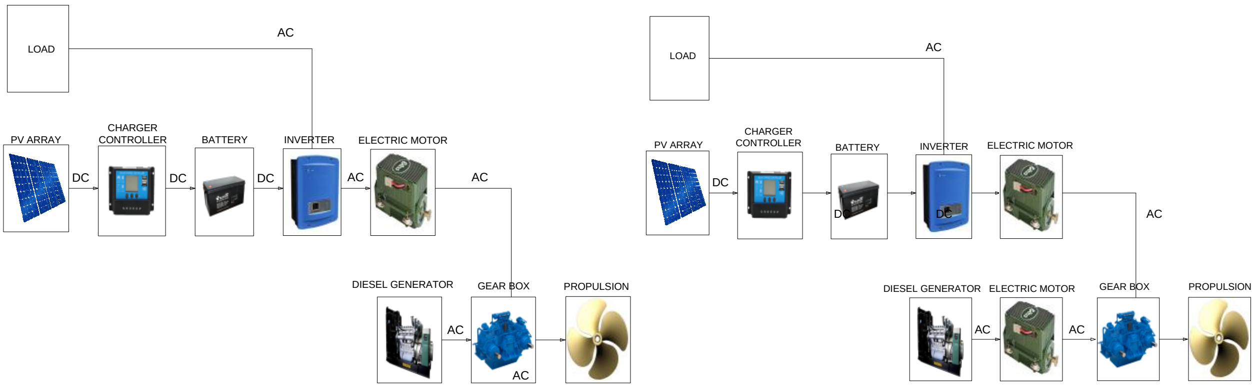

Figure. 7. (a) & (b) Scheme of Hybrid

The Table below shows the results of calculating the ship's exhaust emissions. There is the numerical magnitude of the exhaust gas emission comparison. It can be seen that the most emission is CO2, followed by NOx, CO, etc.

TABLE 8.
EXHAUST EMISSION

No	Pollutant classification	Emision factor (kg/ton)	Before (kg)	After (kg)
1	NOx	57	229.31	131.034
2	SOx	0.7	2.816	1.609
3	CO	7.4	29.770	17.011
4	CO2	3170	12752.87	7287.35
5	VOC	2.4	9.655	5.517
6	Pm	1.5	6.034	3.448

There is a significant decrease, reach to 57%. This occurs due to a decrease in fuel consumption which results from lower exhaust emissions. The fuel reduction was caused by changing the conventional system to a hybrid configuration. The hybrid scheme uses the power from an electric motor, thereby reducing the diesel fuel used. However, the above results when using full speed. While table 9 below shows the results of using different speeds.

TABLE 9.
EXHAUST EMISSION WITH VARIOUS SPEED

No	Pollutant classification	8 Knot	7 Knot	6 Knot
1	Nox	88.270	77.36	66.451
2	Sox	1.084	0.950	0.816
3	Co	11.460	10.043	8.627
4	Co_2	4909.062	4302.324	3695.586
5	Voc	3.717	3.257	2.798
6	Pm	2.323	2.036	1.749

This configuration can vary the speed, starting from a minimum of knots and a maximum of 9 knots. The change in speed also results in decreased exhaust emissions. The decrease is due to the load factor or MCR of the machine being used, which is not entirely 100%. The smaller MCR produces a low speed, so the lower speed does not consume much fuel.

V. CONCLUSION

From the discussion above got, a conclusion can be taken:

1. A hybrid configuration can reduce exhaust emissions by about 57%. This is in line with the government's efforts to reduce emissions.
2. Solar energy in Indonesia sometimes varies. For the rainy season, using solar energy may be less effective but can reduce emissions, although not extensively.
3. It takes other energy experiments, such as ocean energy, wind, and others, to reduce air pollution caused by ships.

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