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Systematic Review of Solar and Wind Power Plants for 14-Meter Fishing Boats

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***Abstract*— the use of fossil fuels is becoming increasingly expensive, and the amount is limited. Utilizing wind and solar energy sources onboard fishing vessels during operation is one of the solutions to reduce operational costs. This article presents a study on applying solar photovoltaic (PV) and wind turbines for a 14-meter BSC (Blue Swimming Crab) fishing vessel in Rembang Regency, Indonesia. This study discusses the use of renewable energy sources that can be applied to meet onboard electricity needs and their economic impact. This analysis considers to operating system scenario for seven days catching the BSC in the Java Sea. The calculation results show that the solar PV and wind turbine energy that can be utilized as electrical energy are 22,960-Watt h. The required battery is 20 units at 100 Ah 12 Volts and an investment cost of USD 21,084. The advantage of applying this technology is an operational cost saving of 16%, which can increase fishermen's income by 11%. The challenge of a hybrid or electric propulsion system is fantastic, using the serial configuration of the power topology, and the result of preliminary estimates of the investment value is approximately 173,277 USD.**

Keywords— fishing vessel, hybrid/electric propulsion, Java Sea, renewable energy, solar PV, wind turbine

I. INTRODUCTION

The increasing price of diesel fuel has an impact on traditional fishermen. Erratic fishing income made them object to the increase in fuel prices set by the government. Meanwhile, subsidized diesel used to fuel boats has increased from IDR 5,150 to IDR 6,800 per liter [1]. Data regarding the unstable exchange rate of fishermen from year to year is also caused by the uncertain income of fishermen because it is influenced by increasing business costs, especially the cost of fuel oil [2]. Alternative renewable energy sources like wind and solar can be used for ship propulsion, especially on medium- and small-scale vessels. They can also be used for lighting, navigation, and other uses that reduce fuel use greenhouse gas emissions (GHG) and fuel cost [3].

In line with this, Indonesia also commits to achieving net zero emissions in 2060 where to support this target, the government recently declared to increase emission reductions from 29% to 31.89% in 2030 as stated in the document of Nationally Determined Contribution (NDC) latest [4]. Besides that, by 2025, Indonesia has a lofty goal of including 23% of new and renewable energy sources in its energy mix [5].

Solar and wind energy use is carried out on a Blue Swimming Crab (BSC) fishing vessel with a 14-meter length in Rembang, one of the centers for BSC fishermen in Indonesia which uses trap fishing gear with the highest selectivity compared to other fishing gear [6]. One of the major economies in Rembang Regency is the fishing industry, which includes catch fisheries. The largest marine fisheries products in the province of Central Java have been produced here [7], with the vast majority of fishing boats being small, less than 10 gross tonnages (GT) in size [8].

With the vessel's existing condition, it is necessary to calculate and analyze opportunities for using renewable energy to meet the electricity needs on board, including replacing equipment that originally used fossil energy sources. Lighting, navigation and communication equipment, BSC streamers, BSC storage cooler boxes, and more have a great opportunity to be supplied with renewable energy sources from solar and wind. Moreover, from an economic calculation, it can be analyzed that there are savings compared to fossil energy sources. The vessel used in this study is the Bugisan-type vessel in Rembang, which usually operates in fishing

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grounds with a distance of 20-40 sea miles from the coast for more than 5 days.

The problem of the layout of additional equipment that affects the stability of the vessel is not discussed in this research, and still maintains the existence of the main propulsion diesel engine. Calculations and analysis focused on the capacity of electrical energy that can be generated from the open space of the vessel and its utilization. The challenge of using hybrid/electric propulsion on this vessel is also a matter of discussion which is presented with some simple calculations and analysis.

A. Solar Energy

Solar energy systems are powered by solar resources, or solar radiation in technical terms. Atmospheric processes influence ground-level solar energy systems' access to solar radiation. The most frequently used phrases to describe solar radiation are divided into two categories [9]:

1) Solar irradiance (measured in W/m^2) is the amount of power (instant energy) incident on a surface of one square meter every second.
2) The amount of incident solar energy per unit area over a certain period is indicated by solar irradiation, which is measured in MJ/m^2 or Wh/m^2 (hour, day, month, and others)

The following three solar resources are significant for solar energy applications [9]:

1) Direct Normal Irradiation (DNI) is the amount of direct solar radiation from the solar disk and the area nearest to the sun (a 5° circumsolar disk centered on the sun). DNI is a crucial component for high-performance cells in concentrated photovoltaic (CPV) technologies and concentrating solar collectors in concentrated solar power (CSP).
2) Global Horizontal Irradiation/Irradiance (GHI): total radiation received on a horizontal plane, including direct and diffuse radiation. GHI serves as standard radiation for climatic zone comparisons and is a crucial input for calculating radiation on flat plate collectors.
3) Global Tilted Irradiation/Irradiance (GTI) is also known as the total radiation received on a surface with a fixed or sun-tracking tilt and azimuth. It is the total of the direct and reflected dispersed radiation. Another phrase used is Plan of Array (POA) irradiation/irradiance. When this happens, GTI in photovoltaic (PV) applications only comprises diffuse and reflected components. GTI can also occasionally be impacted by shadows from nearby topography or objects. This condition typically occurs when the sun is overhead at low angles.

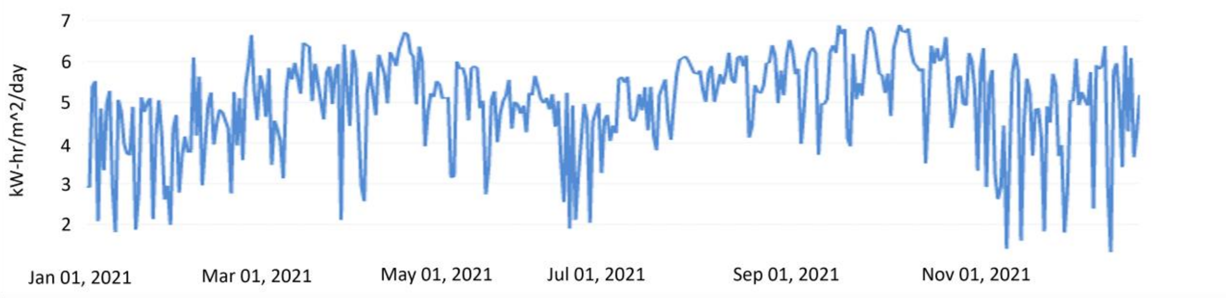

Figure 1. Java Sea All Sky Surface Shortwave Downward Irradiance (kW-hr/m^2/day) in 2021 [17]

In Java Sea, as shown in Fig. 1, the potential energy of solar is between 1.32 – 6.9 kWh/m^2/day, with an average of 4.98 kWh/m^2/day.

B. Photovoltaic system

Photovoltaic (PV) and Concentrated Solar Power (CSP) are the two main categories of solar energy technology [9]. In Indonesia, PV technology will play a significant role in the country's energy mix. Additionally, it is a desirable choice the small-scale energy distribution, especially in the isolated regions of eastern Indonesia. Local mini-grids or off-grid systems are frequently a less expensive option than extending the grid to the remaining electrified homes [10].

In marine applications, PV module efficiency in naval conditions was tested using Maximum Power Point Tracking (MPPT) [11]. There are two approaches to constructing a modern solar-powered boat. First, a large vessel is powered by a hybrid of solar and diesel energy, while a small vessel is powered entirely by solar energy. PV is extremely sensitive to changes in the amount of solar energy and the surrounding temperature. A small change in ambient temperature or sun irradiation could greatly impact how much power PV systems produce [12].

C. Wind Energy

Wind turbines are far more difficult to implement on ships than maritime photovoltaics. The use of wind power generators is still in its infancy and faces many challenges. The abundance of wind resources at sea is the principal benefit of employing a wind generator on board. In comparison to land, water has substantially higher wind generator generation efficiency. However, smaller, slower-moving ships do well in wind power [13]. Wind turbines are divided into: horizontal axis wind turbines (HAWT) and vertical axis wind turbines (VAWT). According to Figure 2., the rotational axis of a

VAWT is perpendicular to the ground while that of a HAWT is parallel to the wind stream. The advantages of HAWT include a better power density, higher aerodynamic efficiency, a lower cut-in wind speed, and a reduced cost per unit of output power.

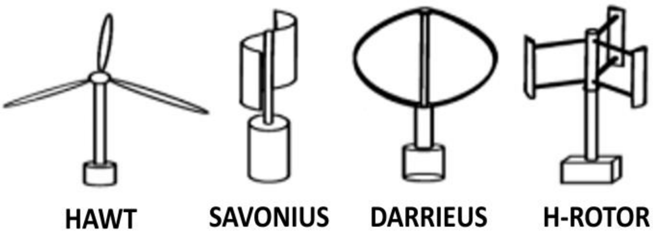

Figure 2. Wind Turbine type [13]

Because of the low center of gravity, VAWT can be built lower and more stable. It also does not require yaw mechanisms, rudders, or downwind coning. It is also simple to conduct maintenance because the electrical generator can be placed lower. It also operates more safely thanks to its lower rotational speed, produces less noise (low tip speed ratio), and is less affected by the constantly changing gravitational loads that would otherwise restrict it.

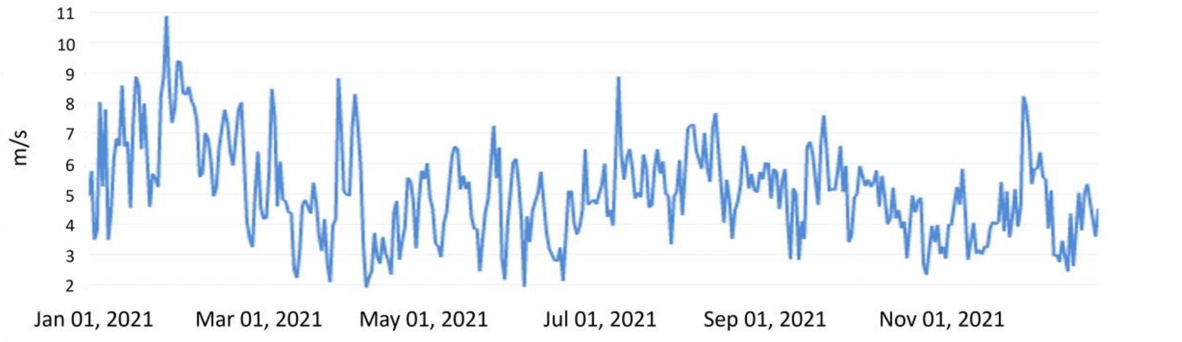

Figure 3. Java Sea wind velocity (m/s) in 2021 [17]

In the Java Sea, as shown in Fig. 3, the potential energy of wind is between 1.91 – 10.88 m/s, and the average is 5.07 m/s.

D. Battery

Batteries are the most often utilized Energy Storage Systems (ESS) in boats. However, alternative ESS technology combinations should be carefully assessed for onboard use concerning their technical properties, costs, weights, and sizes [19]. Due to their significantly higher energy density, lower cost compared to other technologies at the same energy level, and prior experience in the transportation industry, batteries are the most widely used energy storage technology. Batteries are made structurally of electrodes, electrolytes, and separators, while the performance depends on the electrode type [20].

Based on the characteristics in Table 1, Lithium-Ion has the best energy density compared to other types. In addition, Lithium-Ion also has a long service life and good efficiency, although the price is quite high. However, for marine applications, energy density should be the main consideration in selecting a battery because it is closely related to the available space capacity and the ship's stability function.

TABLE 1.
POPULAR BATTERY TYPE CHARACTERISTICS [19].

Battery Type	The energy density (kWh/kg)	Power density (kW/kg)	Efficiency (%)	Lifetime (Cycle)	Capital Cost ($/kWh)
Lead – Acid	30-50 x 10^{-3}	75-300 x 10^{-3}	70-90	500-1000	70
Nickel – Cadmium	50-75 x 10^{-3}	150-300 x 10^{-3}	60-65	2000-2500	300
Nickel Metal Hydride	60-100 x 10^{-3}	200-1500 x 10^{-3}	65-90	750	300-500
Lithium - Ion	100-200 x 10^{-3}	80-2000 x 10^{-3}	85-90	600-2000	200-700

E. Utilization of renewable energy sources for needs on board

Equipment such as lighting, navigation, communication, BSC storage cooler boxes, and more can be powered by renewable energy sources like solar and wind. According to [14], a study of mini wind turbines as an alternative source of electrical energy for navigation lights on the fishing vessel is quite helpful by turning on three series of LED lights for 125.6 hours. In general, the design of a hybrid boat focuses on three key areas: (1) sails that create the most thrust; (2) a system that generates electricity from solar cells to power the ship; and (3) the shape of the ship's hull for minimal resistance and excellent mobility [15]. Another study mentions that the ideal battery for 10 GT electric fishing boats in the Natuna Sea is 6,000 Ah, with a range of around 14 NM, a speed of approximately 7 knots, and fishing activities of approximately 6.5 hours [16].

II. METHOD

A. Literature study

A literature study was carried out to understand the theories and concepts related to applying renewable energy using fishing vessels. This literature study used books and journal articles, as well as direct information from fisherman users

B. Collecting data and arrangement

Data collection was carried out in 3 ways, 1. data collected through direct measurements in the field to obtain the main dimensions and layout of the fishing vessels used as a reference in this study, 2. data obtained from interviews with fishermen or fishing boat skippers to obtain information on patterns of fishing operations and other necessary technical information, 3. technical data related to renewable energy equipment and devices that can be applied to fishing vessels.

C. Selection of the power system

The most suitable power system to operate on a fishing boat was selected at this stage. To meet electricity needs, it is necessary to consider the ease of operation for fishermen

D. Calculation of load and energy resources

Calculating of the load to be replaced with renewable energy was carried out carefully by considering the estimated load of the entire fishing vessel.

Solar PV energy can be interpreted as solar energy that can be harvested by solar panel modules obtained from equation (1)

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

Where P_{PV} is the PV module's peak power in watts, ηs indicates how effective the PV system is, in line with the energy loss brought on by converters, wires, temperature, or others. The term "charging efficiency" (abbreviated "ηc") refers to the amount of power lost while transferring solar energy to a battery. The number of PV panels that need to be adjusted is x_1, solar radiation is measured in kW/m^2 as I_{rr}, and G_{STC} is the radiation at 1 kW/m^2 under standard test conditions [21].

E. Calculation of battery bank

Battery capacity calculations are carried out to determine the amount of battery provided to cover the electrical load on board. For emergencies, 10 - 15% of the total capacity can be added [16].

Equation (2) is used to determine the battery's energy. Temperature, charging or discharging current, and other factors affecting battery capacity are not considered.

$$E_{batt} = \frac{V_{batt} . C_{batt} . x_2}{1000 . \eta_d} \qquad (2)$$

Where V_{batt} is the battery's nominal voltage in volts, C_{batt} is in Ampere-hour (battery capacity), ηd is the efficiency of battery discharging that depicts the energy lost during the discharging process energy, and x_2 is the quantity of battery that will be improved [21].

F. Calculation of economic effect

After describing all the equipment needed to install a renewable energy system on board, the next step is to calculate the cost benefits of the system. Collecting price data for each piece of equipment is essential to estimate the savings or profits of installing the system.

G. Challenges of hybrid/electric propulsion application

The challenge of hybrid/electric propulsion has recently become an interesting topic in research, including its application to small-scale fishing vessels. This study also briefly describes these challenges when applied to a 14-meter fishing boat in Rembang.

III. RESULTS AND DISCUSSION

A. Main dimensions and layout of a fishing vessel in Rembang

In this study, the fishing vessel used for the research object was a 14-meter (<10 GT) long BSC fishing vessel based at Tasik Agung Port, Rembang (see Fig.4.) with the main dimensions as follows:

Length Over All (LOA) = 14.2 m
Breadth (B) = 3.5 m
Height (H) = 0.7 m
Vol. Displacement ≈ 17.5 m^3
Main Engine = Mitsubishi 120 PS
Type of vessel = Bugisan

Figure. 4. BSC Fishing Vessel at Rembang Regency (picture taken by Author.)

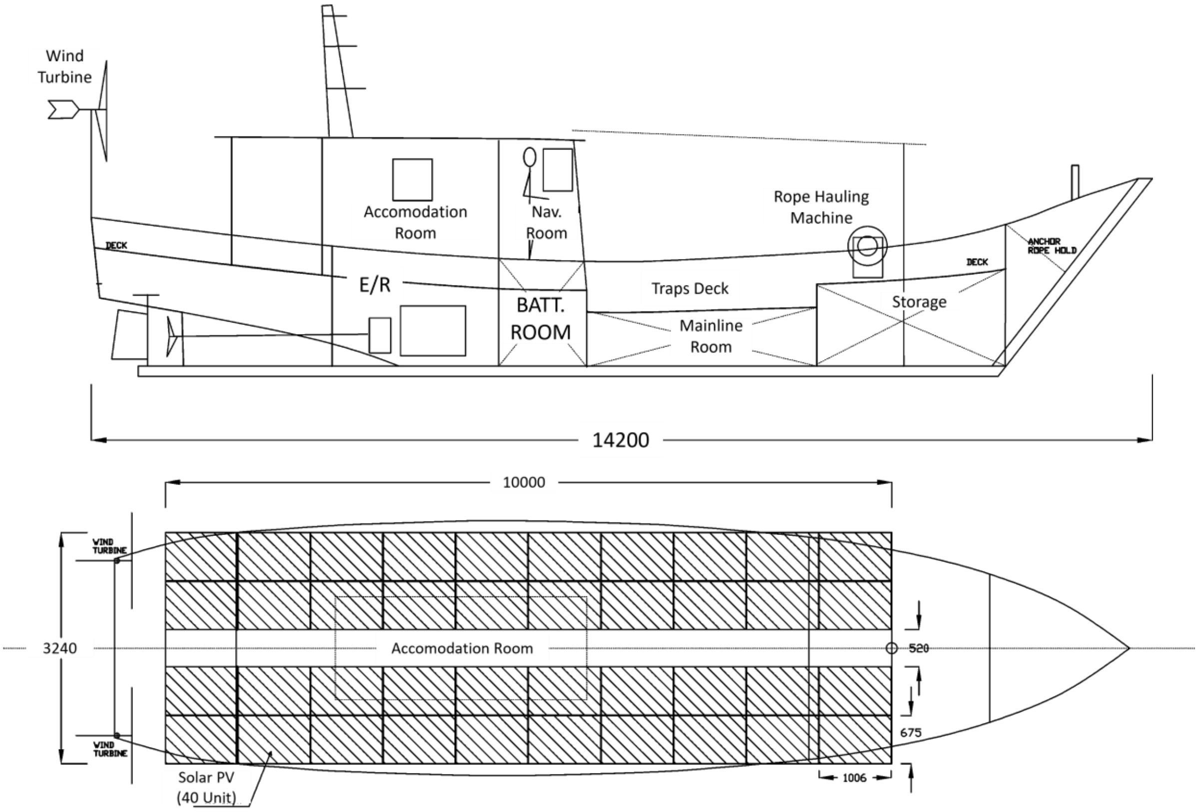

Figure 5. Solar PV and wind turbine arrangement on BSC Fishing Vessel

Based on Figure 5. above, the placement of solar PV and wind turbines can be set up in an area that does not interfere with fishing activities in crab fishing operations so that solar PV can be placed above the accommodation space up to the front of the mast, and the wind turbine can be placed at the stern (port and starboard side). In installing of the equipment, the reinforcement structure must be considered. In this study, 40 units of solar PV @ 100 watts and 2 units of wind turbines @ 40 watts can be installed.

B. *Selection of the power system*

In choosing a system suitable for installation on fishing boats to meet electricity needs, it is necessary to consider the ease of operation for fishermen. We can combine solar and wind energy sources through a scheme described in Figure 6.

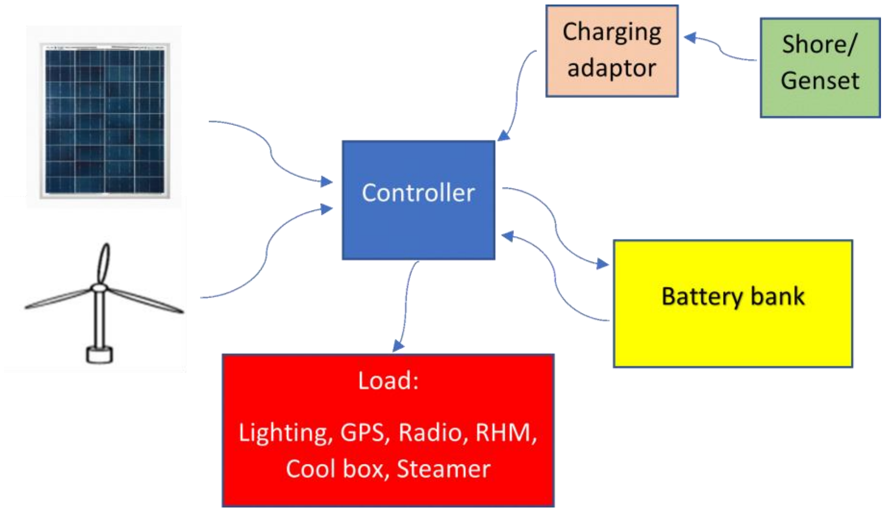

Figure 6. Scheme of power system

Based on that scheme, the energy source is supplied not only by solar PV and wind turbines but also by the port power grid and generators if needed as a backup.

C. Calculation of load and energy resources

In this study, the energy required to be analyzed is the electricity demand that can be generated onboard a 14-meter fishing vessel to meet the lighting, navigation, communication, BSC storage cooler boxes, and crab steamer, with detail of the need per day as follows:

TABLE 2.
LIST OF ELECTRICITY REQUIREMENTS ON BOARD (14-M FISHING VESSEL) IN REMBANG

Equipment	Power (Watt)	Operating Hour	Watt Hour
Lighting	100	12	1,200
GPS	20	24	480
Radio	20	24	480
Cool box	200	24	4,800
Crabs Steamer/cooker	2,000	4	8,000
		Total =	14,960
		+ 15%	17,204

According to Table 2, the total load requirement on board is about 17.2 kWh. Moreover, based on a spatial plan, 40 units of solar pv and 2 units of wind turbines can be installed with the total energy produced is 22,960 Watt hours or 22.96 kWh (1) with ηc=85% and ηs=80%. It means the system has a reserve of 25% to overcome other losses.

Detailed specifications of solar panels and wind turbines are shown in Table 3 below [18]:

TABLE 3.
SPECIFICATION OF ENERGY SOURCE

Solar PV:	
Model No.	ALP-100A
Pmax (W)	100 W
Voc (V)	21.4 V
Isc (A)	6.3 A
Vpm (V)	17.7 V
Ipm (A)	5.7 A
Size (with x length x depth)	675x1,006x35 mm
Weight (Net)	7.5 kg
Wind Turbine:	
Model	24 V
Power Rating min (5 m/s wind speed)	40 W (1.45 A)
Power Rating max (15 m/s wind speed)	483 W (17.5 A)
Cut in windspeed	2.5 m/s
Minimum tower height	6 m on land
Turbine diameter	1,200 mm
Turbine net weight	7.8 kg

D. Calculation of battery bank

Lithium-ion batteries are currently a mainstay in energy storage. In this study, we select the type of battery with the following specifications [23]:

TABLE 4.
SPECIFICATION OF BATTERY

Voltage	12 Volts
Nominal Cap./Ah (25ºC, 0,2ºC)	≥ 100Ah
Energy	1,280 Watt-hour
Battery Cell Composition	Lithium-Iron-Phosphate
Item Weight	14 kg
Cycles	>3,000 at 100%
Operation Temperature	-20 - 60º C
Item Dimensions	329 x 172 x 223 mm

Using equation (2), we can determine the number of batteries needed to meet the electricity needs on board with the battery specifications in Table 4 above. With ηd 85% and 15% for emergencies, the total battery required is 14 units. To support an operational period of up to 10 years, the batteries that must be provided on board are 1.5 times the total requirement, so the total battery installed is 20 units, and the total weight is 280 kg

E. Calculation of economic effect

In calculating the economic impact, we calculate the amount of investment required to procure solar and wind power generators, then we compare the difference in fishermen's operational expenses before using renewable energy and after.

As a reference for calculating the economic impact, and based on the results of interviews and discussions with fishermen in November 2022, the pattern of BSC fishing operations must be determined, namely: the vessel operates for 5 days or more at sea with details, including depart from the fishing base in the early hours of the night to the fishing ground in the morning (travel around 3-4 hours or 20-30 sea miles), then leave the trap setting until the next morning, then haul/lift the trap (about 3-4 hours), then continue looking for a new fishing ground then the second setting. After the setting is continued with BSC processing (steamed, air dried, stored in a box chilled with softened ice cubes), the crew rests. The work continues the next morning, repeating 5-7 times, then going home with the trap condition in the setting/submerged position. Then after arriving on land, the BSCs are unloaded and further processed on the mini plan (usually done by their wives). Next, the fishermen take a break for 2-3 days, then set off again to haul the traps that have been set previously, and then repeat the pattern by adjusting the result. If the result is unsatisfactory, they decide to go home and rest longer (not to go to sea) by bringing their fishing gear.

1) Power plant investment

The following is a breakdown of the investment required to use renewable energy on board [18,23,24]:

TABLE 5.
POWER PLANT INVESTMENT

Equipment	Unit	Price USD
Solar PV 100 Wp	40	6,400
Wind Turbine 40 Watt	2	3,152
SCC 100 A	2	900
Inverter 2,500 Watt	1	1,282
Battery Life-Po4	20	8,000
Adaptor Charging	1	350
Installation	1	1,000
	Total	21,084

The total investment in Table 5 above is an estimated calculation based on needs with quality to operate at sea where the battery and solar PV components dominate in this study. Other alternative products can be used but must consider the operating environment. Moreover, additional investment for equipment such as coolboxes and cookers is calculated excluding the power plant investment.

2) Operational cost

With the above operations pattern, the amount of expenditure that must be met for needs during operations is as follows:

TABLE 6.
OPERATIONAL COST

Item	Unit	Price USD	%
Diesel fuel	200 liters	110	41
Bait (cowhide)	100 kg	47	17
Ice cubes	10 cubes	34	13
LPG 3kg	3	7	3
Food supplies	1	60	22
Mechanical spare part	1	10	4
	Total	268	100

Based on Table 6 above, the biggest need in the operation of this BSC fishing vessel is the purchase of fossil fuel (about 44%) consisting of 41% diesel fuel and 3% LPG. Other needs sequentially start from food supplies (22%), bait (18%), ice cubes (13%), and spare parts (4%).

3) The income per trip estimation

The income data of the BSC fishermen were obtained from the daily records of BSC collectors when the field study was carried out. BSC prices fluctuate based on demand and supply when the transaction is made, where the price of steamed crab is USD 4 per kg, and the average catch ranges from 130 kg to 160 kg. It means the gross is equal to USD 520 - USD 640. So the total net income is USD 252 to USD 372.

The distribution of results from the net income is divided by 4 with details of 1 part for the vessel and 3 parts for the crew. So the vessel owner gets a share of USD 63 to USD 93 per trip.

4) Benefit

In calculating these benefits, a comparison of operational costs is made before using solar PV and wind power and after using it. Based on these calculations, solar PV and wind power can save on ice blocks and LPG spending of USD 41 or the equivalent of 16%, so the fishermen and vessel owner can increase their income by about 11%.

TABLE 7.
COMPARISON BETWEEN USING RENEWABLE AND WITHOUT RENEWABLE ENERGY

Item	Using RE (USD)	Without RE (USD)
Investment	21,084	0
Operational cost / trip	227	268
Maintenance cost/ trip	10	10
Net income max/trip	103	93

Based on Table 7 above, to calculate the Break Even Point (BEP) of the investment value, the condition used as a reference is that the vessel is not used as a component of the calculation because the vessel as the object of study is more than 20 years old. In the profit-sharing system in fishermen, the vessel gets 1 part, and the vessel's owner is also a crew member, so in BEP calculations, the total share for the vessel is used to cover maintenance costs and return on investment for the vessel power plant.

A simple BEP calculation for the above study is as follows:

BEP Trip = Investment : (Net Income – Maintenance cost)

BEP Trip = 21,084 : (103-10) = 226 Trip

If, in one year, the average operation is 30 trips, the BEP year is 7.5 years.

F. Challenges of hybrid/electric propulsion application

The topic of hybrid/electric propulsion has now become a hot topic for discussion in the research world, especially on a small-scale boat. Hybrid/electric propulsion has the potential to be practical for fishing vessels, and the proper configuration for this vessel is serial configuration [19] (see Figure 7.).

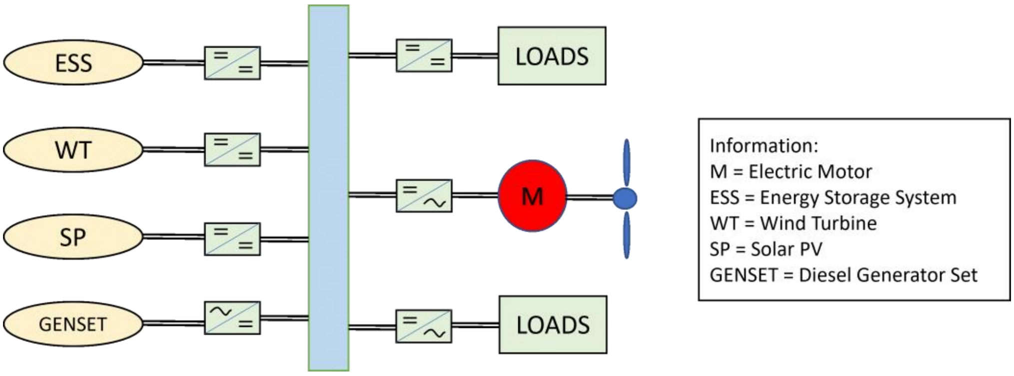

Figure 7. Serial hybrid power topology for 14-meter fishing vessel

This configuration (Figure 7) has advantages, including getting energy from various sources, including diesel generators, solar PV, wind turbines, and batteries. Since the system collects and distribute its entire electrical output via a single bus bar, it is possible to employ various working modes, even with just one (e.g., only battery power) [19].

It would be quite interesting if this propulsion application could be applied to the 14-meter BSC fishing vessel in Rembang Regency. To start implementing, the first thing to do is to study the calculation of the required power. The method can be through modeling, software assistance, or literature data obtained in the FAO manual [22]. Then after knowing the motor power, determine the fishing operation scenario, then calculate the total electricity loads on board, including the type and quantity. Furthermore, the battery capacity and charging system calculation must be adjusted to the predetermined scenario. The last is to estimate the boat's light and dead weight. Also, investment calculation must consider the cost benefits of using the system.

1) Power and motor requirements

Using the FAO manual, the speed/length ratio for fuel-saving speed is determined in the following equation [22]:

$$\text{Speed (knots)} = 2.1\, x\sqrt{Waterline\ length\ (m)} \tag{3}$$

For a 14-meter vessel with a length in the waterline of about 13-meter, the efficient speed is 7,6 knots, and the power requirement is approx. 80 HP or 60 kW [22].

2) Fishing operation scenario

In this application, the scenario of a 14-meter BSC fishing vessel using hybrid/electric propulsion is illustrated below:

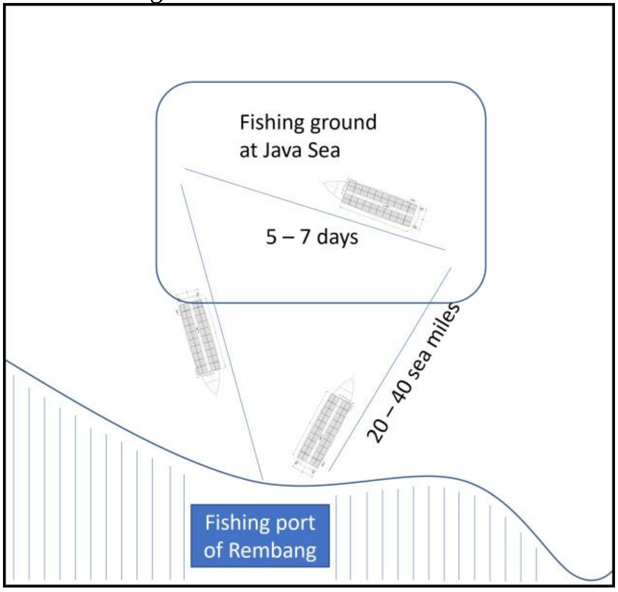

Figure 8. The operational scenario of a 14-meter BSC fishing vessel

Based on Figure 8 above, the scenario can be explained in detail as follows:

a. The journey from the port to the fishing ground is 3-4 hours;
b. Setting the BSC traps for about 30 minutes;
c. Waiting while charging the battery until the next morning;
d. Lifting/hauling the BSC traps takes about 3-4 hours;
e. Searching for a new location and setting the BSC traps for the second time;
f. The caught crabs are processed and then put in a storage container;
g. Till the following morning, relax while the battery is being charged;
h. d, e, f and g activities are carried out repeatedly for up to 7 days, or the storage space is full, then return home to port.

3) Load calculation

The total load of the hybrid propulsion in this vessel daily is in Table 2, added a 60 kW motor that operated for 4 hours. Summed up a margin of 15%, the total load equals 293 kWh.

4) Battery capacity and charging system

According to the total load calculated above, the minimum capacity of the battery is about 24,433 Ah, which is calculated by dividing the battery voltage by the kWh load [16]. Moreover, according to equation (2) and the specifications in Table 4, the number of batteries that must be provided is about 240 units with a total weight of approx. 3.4 tons.

In order to meet the electricity needs on board, a battery charging system is needed which is sourced from renewable energy from solar PV and wind turbines. However other energy sources from the diesel generator are needed as a backup, with an estimated power of about 30 kW. In addition, it is recommended that the energy source for charging batteries comes from the power grid on the mainland when the vessel is leaning on the port.

5) Weight calculation

The weight calculation of the vessel is important, considering that the battery quantity for storing energy is very significant so that the vessel can operate normally. If the volume displacement of the vessel is approx. 17.5 m^3, the mass displacement is 17.5 m^3 x 1.025 tons/m^3 (density of seawater), which is equal to 17.94 tons.

Mass displacement = LWT + DWT, where LWT is Light Weight Tonnage, and DWT is Dead Weight Tonnage.

- Calculation of DWT
  The moveable components and payload weight are included in the DWT. The payload for this vessel has been estimated for the max. 1 ton of crabs. Moreover, moveable components include freshwater, feeding supplies, crews, diesel fuels, traps, bait and the reserves, as follows:

TABLE 8.
MOVEABLE COMPONENTS

Item	Weight (ton)
Freshwater (4x25x10/1000 kg)	1
Feeding supplies (4x5x10/1000 kg)	0.2
Crews (4x80/1000 kg)	0.32
Diesel fuels	0.2
Traps (1000x1.5/1000 kg)	1.5
Baits	0.2
Reserves (0.45%xmass displ.)	0.08
Total	3.5

  Based on Table 8 above, a total moveable component of 3.5 tons is obtained, so the DWT is 4.5 tons.
- Calculation of LWT
  LWT consists of hull structures, machinery, and other equipment. Calculating the weight of the hull structure can be done by approaching the boat's surface area and weight of the material per unit area, where surface area = full breadth amidships x Lenght over All x 0.93 [25]. The following is a breakdown of the estimated LWT calculation.

TABLE 9.
LIGHT WEIGHT TONNAGE ESTIMATION

Item	Weight (ton)
Hull Structure (including superstructure)	4.51
Machinery:	
Diesel Generator Set 30 kW	0.50
E-Drive 60 kW	0.20
Line Hauler Electric	0.30
Other Equipment:	
Battery 240 unit @ 14 kg	3.40
Solar PV 40 unit @ 7.5 kg	0.30
Wind Turbine 2 unit @ 7.8 kg	0.02
Refrigerator System	1.00
Propulsion System	0.30
Total	10.53

Based on the calculation of DWT and LWT above, it is known that the amount is 15.03 tons, so there is a difference within mass displacement, which is around 2.9 tons. It means that the vessel still has a reserve capacity that can be used for other fishing purposes.

6) Investment calculation

The total investment required for the procurement of a new 14-meter BSC fishing vessel with a hybrid/electric propulsion system is estimated as follows [18,23,24]:

TABLE 10.
INVESTMENT IN 14-METER BSC FISHING VESSEL

Item	Unit	Price (USD)
Hull Structure (including superstructure)	1	12,500
Machinery:		
Diesel Generator Set 30 kW	1	6,250
E-Drive 60 kW	1	2,500
Line Hauler Electric	1	3,125
Other Equipment:		
Battery 100 Ah 12 V Life-Po4	240	96,000
Solar PV 100 Wp	40	6,400
Wind Turbine 40 W	2	3,152
System Control and Inverter	1	3,000
Adaptor	1	350
Refrigerator System	1	12,500
Propulsion System	1	3,125
Traps	1000	3,125
Installation	1	18,750
Total		173,277

With the total investment stated above, fishermen in Indonesia still require a very high cost even though the operation is cheaper. Intensive socialization and understanding are needed to make the Energy Transition program successful, especially in the marine and fisheries sector.

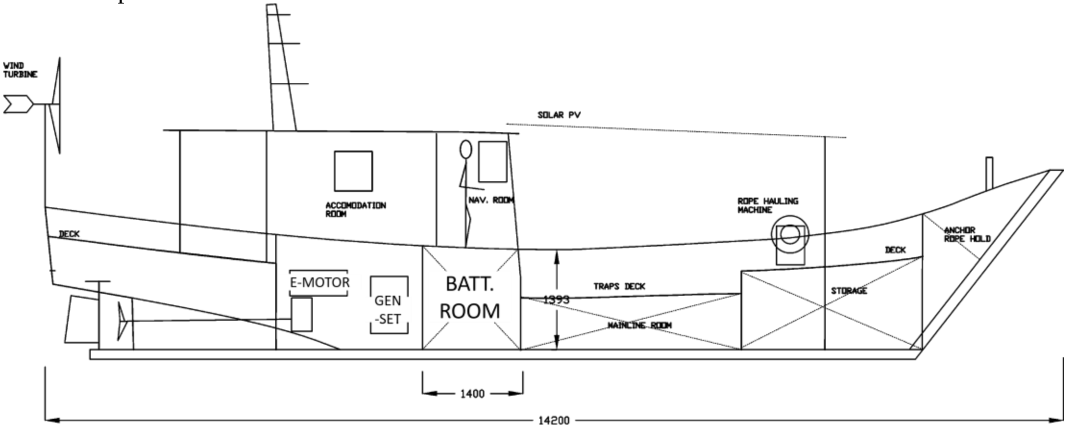

Figure 9. Hybrid/electric propulsion arrangement on BSC Fishing Vessel (estimation)

Figure 9. depicts the estimated arrangement layout of the hybrid/electric propulsion system with the motor room, generator room and battery room. A more in-depth calculation is needed regarding the layout plan for this system to be more effective and efficient.

IV. CONCLUSION

Considering the result of the previous discussion, it can be concluded that renewable energy sources can be applied to meet the electricity needs onboard. Based on the calculation results, it is obtained that solar PV and wind turbine energy that can be used as electrical energy is 22,960 Watt Hour, used for lighting, GPS, radio, coolbox, and crabs steamer/cooker. The required battery is 20 units @100 Ah 12 Volts and an investment cost is about USD 21,084. The advantage of applying this technology includes an operational cost saving of 16%, increasing fishermen's income by 11%.

The challenge of a hybrid/electric propulsion system is very fantastic. Based on the serial configuration of power topology, the preliminary estimates of calculation result in the required total load of 293 kWh, with the battery requirement of 240 units, equivalent to 3.4 tons of Life-Po4 type, so the total investment is about 173,277 USD. Moreover ,the last important thing is the weight calculation in terms of the weight capacity of the displacement compared to the weight of the vessel (DWT and LWT). The total mass displacement is around 17.94 tons, DWT is about 4.5 tons, and LWT is about 10.53 tons, so a reserve capacity of about 2.9 tons can be used for other fishing purposes.

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