PROJECT-BASED LEARNING FOR SUSTAINABLE TOURISM: PROTOTYPING A SOLAR-ELECTRIC BOAT IN A POLYTECHNIC SETTING

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ABSTRACT
Mangrove tourism areas are vital ecosystems that function not only as natural attractions but also as coastal buffers supporting biodiversity and environmental balance. However, tourism activities predominantly rely on fossil-fuel boats that cause air and water pollution, noise, and ecosystem disruption. This research aims to design a concept of an electric boat integrated with a photovoltaic (PV) system as an environmentally friendly transportation solution for mangrove tourism. The study applied a Research and Development (R&D) approach, including literature review, user needs assessment, energy requirement analysis, and detailed engineering design. The results show that the designed boat measures 5 meters in length, 1.8 meters in width, with a draft of 0.6 meters and total height of 1.25 meters. The electrical demand was calculated at 826 W with an operational capacity of 3142 Wh. To meet this demand, four 250 Wp solar panels, a solar charge controller rated at 26.04 A, and a single LiFePO4 battery of 48 V/100 Ah were required. The integration of PV systems demonstrated sufficient energy supply for operation under coastal solar exposure. The design significantly reduces fossil fuel dependence, lowers carbon emissions, minimizes noise, and enhances tourist experiences. This concept contributes to the development of sustainable ecotourism practices in coastal mangrove ecosystems. Future research is recommended to test prototype performance in real operational settings and optimize system efficiency across varying weather conditions.

Keywords: Ecotourism Sustainability; Electric Boat; Mangrove Tourism; Photovoltaic System; Renewable Energy

INTRODUCTION

Mangroves are one of the important ecosystems in coastal areas that have ecological, economic, and social roles. Mangrove forests function as abrasion barriers, carbon sinks, and habitats for various types of flora and fauna. In addition, the mangrove area has also developed into an attractive natural tourist destination, because it presents an educational and recreational experience for visitors. Sustainable mangrove tourism management is expected to be able to provide economic benefits for coastal communities without sacrificing environmental sustainability. Mangrove forests are one of the forest ecosystems with plant groups that can live in areas with high salt levels. It is usually dominated by woody plants and grows along coastlines and subtropics. Mangrove forests have physical functions such as maintaining the stability of the coastline, protecting the coast from abrasion, resisting sidemen, in addition to that mangrove forests have a chemical function, namely producing oxygen and absorbing carbon dioxide and processing waste and mangrove forests have biological functions such as a source of food for marine life, as a breeding ground for marine animals, as a place for animal shelters. Another function of mangrove forests is as a tourist attraction. Of the various functions of mangrove forests, it is necessary to conserve [1][2]. From these conditions, mangrove forests need to be conserved and supervised and maintained, therefore to do this, it is necessary to carry out technological innovations by utilizing solar energy as a source of electrical energy for environmentally friendly boat drives [3][4]. One of the main means in mangrove tourism activities is water transportation using boats. However, most boats in use today still rely on fossil fuel engines. The use of conventional boats poses various problems, such as air pollution due to exhaust gas emissions, engine noise that disturbs the comfort of tourists, and the potential for water pollution due to fuel and oil leaks. This condition is not only detrimental to the quality of ecotourism, but also risks disrupting the sustainability of sensitive mangrove ecosystems.

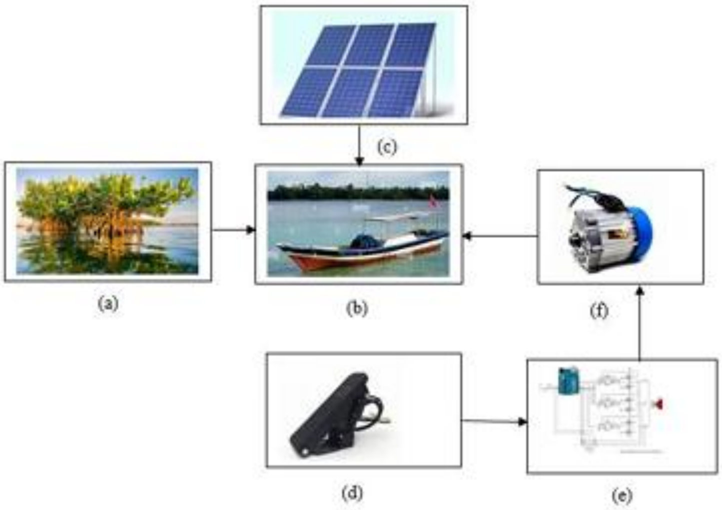


Figure 1. Illustration of the background of the research (a). Mangrove Forest, (b). Boat, (c). Photo voltaic (PV), (d). Speed regulator, (e). Kontroller, (f). Boat Drive Motor

Environmentally friendly energy is an alternative that can be developed to protect the environment of mangrove forests and marine life in mangrove forests and can reduce fuel usage costs to a minimum. In the supervision and maintenance of mangrove forests to answer the question, the use of PV as an independent energy source is also a solution because it is renewable energy. With the use of PV, it is hoped that it will be able to rotate the BLDC motor as a boat drive [5]. As awareness of the importance of renewable energy and sustainable tourism increases, there is a need for environmentally friendly transportation solutions that can reduce dependence on fossil fuels. One of the alternatives that can be developed is an electric boat that is integrated with a photovoltaic (PV) system. The electrical energy generated from the solar panels can be stored in batteries to be used as a power source for the electric motor of the boat drive. This technology is able to reduce carbon emissions, reduce noise, and reduce operational costs in the long term. Therefore, the design of the electric boat concept with an integrated PV system is a strategic step in supporting sustainable mangrove tourism. With the implementation of this concept, it is hoped that tourism transportation will be created that is environmentally friendly, efficient, and in line with the commitment to clean energy development and the preservation of coastal ecosystems.

Calculating Total Electrical Energy

Solar Power Plant (PLTS) planning requires a detailed analysis of energy needs so that the installed solar panel capacity is able to meet the electrical load. This analysis includes the calculation of daily energy consumption, the potential of solar energy on site, and the efficiency of the system.

The first step is to calculate the total electrical energy required by the load in one day with the following formula.

$$E_{Beban}\,(Wh) = \sum Daya\ Terpasang\ (watt) X\ Lama\ operasi\ (jam)$$

The Operation Efficiency of Solar Power Plants is very taken into account, so photo voltaic energy can be formulated as follows:

$$Total\ Daya (Wh) = \frac{Kebutuhan\ Daya\ (Wh)}{Efisiensi\ PLTS}$$

The energy that solar panels can generate depends on the daily average solar radiation intensity (expressed in Peak Sun Hour or PSH).

$$Daya\ PV = Pnominal\ PV\ (w) x\ Waktu\ operasi\ (Jam)$$

The number of solar panels needed in a solar PV plan is:

$$Jumlah\ Panel\ = \frac{Energi\ Yang\ terserap\ (W)}{Daya\ Panel\ surya\ (Wp)}$$

Calculating the Capacity of the Solar Charger Controller (SCC)

The energy generated by the solar panel (PV) has a variable voltage value so a solar charger controller is needed that has a current that is adjusted to the current flowing from the SCC
Arus SCC (Amp)=(Jumlah PV x Daya Panel Surya)/(Operasi Tegangan (V))
In performing SCC surgery to be safe, it is multiplied by a protection index of 1.25 so that the following are obtained:

$$Arus\ SCC\ (Amp) = Arus\ SCC\ x\ 1{,}25$$

Battery Calculation

The battery used is a LiFIPO4 type battery with a voltage of 48 volts/100 Ah with a battery efficiency of 95 %

$$Cadangan\ daya\ \ (Wh) = \frac{Daya\ Terpasang\ \ (Wh)}{Efisiensi\ Baterai}$$

The number of batteries needed is:

$$Jumlah\ Baterai\ = \frac{Cadangan\ Daya\ (Wh)}{Daya\ Baterai\ (Wh)}$$

METHOD

The research methods applied in this study use the Research and Development (R&D) approach as the main basis. This approach provides a structured framework for the design, development process. In the initial stage, a literature study was carried out on journals, scientific articles, research reports, and government regulations related to mangruf and coastal tourism, the technology developed was the concept of a new and renewable energy-based mangrove tourism boat. This study is complemented by a descriptive study approach through direct interviews with the community of mangrove tourism areas to explore the main problems related to the constraints and need for modern tools.

Research Stages

1. Calculating the energy potential and electrical load needs of the boat. The initial stage carried out in this study is to calculate the load of electrical power used on the boat and analyze the needs of solar panels, batteries, SCCs, and boat drive motors (BLDC).
2. Electric Boat Concept Design. Making a boat sketch model for mangrove tourism needs with materials used on boats taking into account the weight of the boat and the life load of the boat.
3. Detailed Engineeringring Design (DED). Compile and adapt the design of the tool concept into a more detailed technical document, namely Detail Engineering Design (DED). This DED document is the main

reference in the tool assembly process to comply with the technical specifications that have been formulated based on the results of the initial study. The final validation of this document is carried out by a team of experts to ensure that the design is feasible to produce and in accordance with the needs of the field. The expected results from this stage Start of Literature Study Descriptive Study – Joint Needs Interview with Partners Design PV integrated electric boat concept and Adjustment of tool concept design by making DED PV integrated electric boat manufacturing.

4. Evaluation: Whether the tool works according to design. The next stage is the technical evaluation of the results of the evaluation of the tool. This evaluation aims to ensure that the tool works according to design and meets established standards of effectiveness and efficiency.

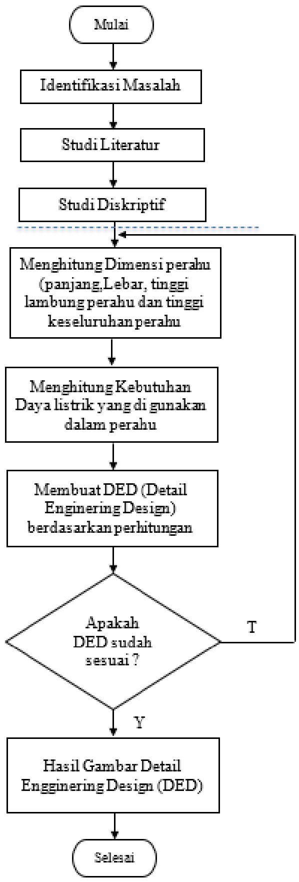


Figure 2. Research flow chart image

RESULTS AND DISCUSSION

Boat Design

The boat is designed with a capacity of two people, with a length of three meters and a speed of 3-4 knots. The planning is in accordance with previous research. For the calculation of the width, load and height of a boat with a length of 5 meters is obtained from the equation:

$L/W = 3.0 - 4.0$

$5/B = 3.0$

B = 1,667 meters

The ratio is a parameter of boat resistance, the greater the ratio value, the smaller the boat resistance.

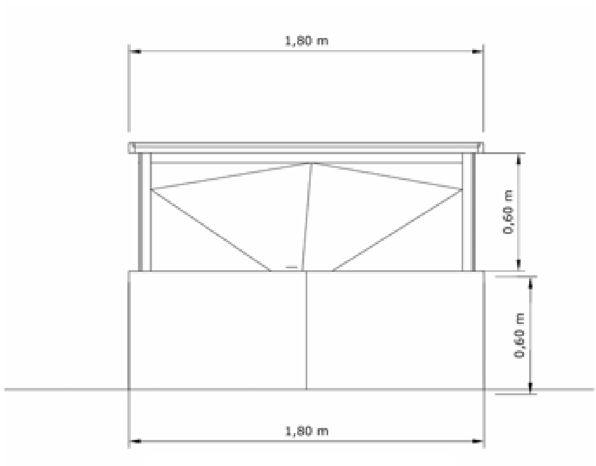
$B/T = 2.7 – 4.8$

$1.667/T = 3.00$

T = 0.617 meters

The width of the boat is approximately 1.80 boat height so that the height of the boat designed can be obtained as:
B = 1.80 H
H = 1.667/1.80
H = 1.25 meters

Thus, it can be concluded that the main sizes of the designed boats are as follows:
Length (L) = 5.0 m
Width (B) = 1.8 m
Load (T) = 0.6 m
Height (H)= 1.25 m



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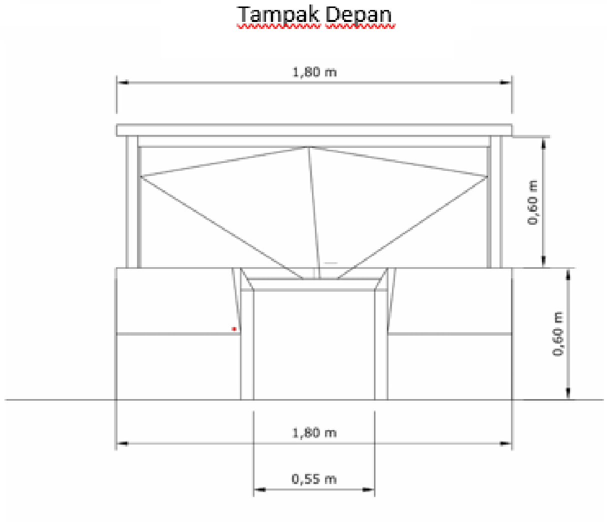

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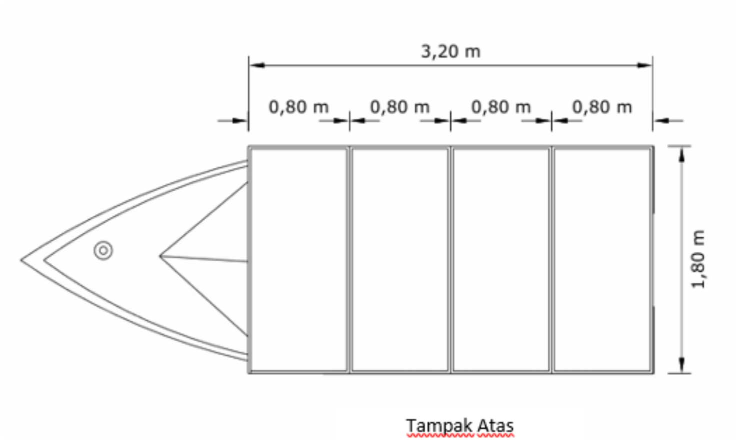

Figure 3. Boat Plans

Determination of the specification of solar power as a source of electrical energy for ships

Table 1. Boat Electric Power

Tool Name	Quantity	Total Electrical Power (W)	Operating Hours	Total Power (Wh)
Communication Tools	1	10	6	60
Spotlight	1	50	1	50
Lighting	2	16	2	32
BLDC	1	500	6	3000
		826		3142

Load Power At the planning is 3142 Wh. Solar PV efficiency = 60 %

$$Total\ Daya(Wh) = \frac{Kebutuhan\ Daya\ (Wh)}{Efisiensi\ PLTS}$$

$$Total\ Daya(Wh) = \frac{3142\ Wh}{60\%}$$

$$Total\ Daya(Wh) = 5237\ Wh$$

Calculating the Number of Solar Panels

The recommended solar panel is 250 Wp assuming charging for 6 hours, it can be calculated as formula:

$$Energi\ Yang\ Terserap = \frac{Total\ Daya\ (Wh)}{6\ Jam}$$

$$Energi\ Yang\ Terserap = \frac{5237\ Wh}{6\ Jam}$$

$$Energi\ Yang\ Terserap = 872\ Watt$$

Number of Panels Needed:

$$Jumlah\ Panel\ = \frac{Energi\ Yang\ terserap\ (W)}{Daya\ Panel\ surya\ (Wp)}$$

$$Jumlah\ Panel\ = \frac{872}{250} = 3{,}491\ buah\ (di\ bulatkan\ menjadi\ 4\ buah)$$

Calculating the Capacity of the Solar Charger Controller (SCC)

$$Arus\ SCC\ (Amp) = \frac{4\ x\ Daya\ Panel\ Surya}{Operasi\ Tegangan\ (V)}$$

$$Arus\ SCC\ (Amp) = \frac{4\ x\ 250\ Wp}{48\ Volt}$$

$$Arus\ SCC\ (Amp) = \frac{1000}{48\ volt}$$

$$Arus\ SCC\ (Amp) = 20{,}83 Ampere$$

In performing SCC surgery to be safe, it is multiplied by a protection index of 1.25 so that the following are obtained:

$$Arus\ SCC\ (Amp) = Arus\ SCC\ x\ 1{,}25$$
$$Arus\ SCC\ (Amp) = 20{,}83\ \ x\ 1{,}25$$
$$Arus\ SCC\ (Amp) = 26{,}0375\ Ampere$$

Battery Calculation

The battery used is a LiFIPO4 type battery with a voltage of 48 volts/100 Ah with a battery efficiency of 95 %

$$Cadangan\ daya\ \ (Wh) = \frac{Daya\ Terpasang\ \ (Wh)}{Efisiensi\ Baterai}$$

$$Cadangan\ daya\ (Wh) = \frac{3142\ Wh}{95\%}$$

$$Cadangan\ daya\ \ (Wh) = 3307\ Wh$$

The number of batteries needed is:

$$Jumlah\ Baterai\ \ = \frac{Cadangan\ Daya\ (Wh)}{Daya\ Baterai\ (Wh)}$$

$$Jumlah\ Baterai\ \ = \frac{3307\ Wh}{48\ Watt\ x\ 100\ Ah}$$

$$Jumlah\ Baterai\ \ = \frac{3307\ Wh}{4800\ Wh}$$

$$Jumlah\ Baterai\ = 0{,}688\ buah\ (1\ buah)$$

CONCLUSION

The results of this calculation were obtained a boat length of 5 meters, a width of 1.8 meters, a loaded height of 0.6 meters and an overall height of 1.25 m with an electrical power requirement of 826 watts with an operating power of 3142 Wh. The need for solar panels (PV) is 4 pieces with a capacity of 250 Wp, the SCC used according to the calculation is 26.0375 Ampere, with the number of batteries used as much as 1 piece with a capacity of 48 volts/100 Ah, the type used is a LifiPO4 battery.

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REFERENCES

Boikh, L. I., Djonu, A., Kiak, N. T., Bria, J. O., Tenis, R., Sigit, A. D. T. P., & Adangla, P. (2023). The development of mangrove tourism activities into edutourism areas in West Oesapa Village, Kupang City (Vol. 7, No. 4). Nusa Cendana University.

Daniel, D., & Sianturi, D. S. A. (2013). Battery performance test for the main load of DC motors of boats returning home. National Marine Journal, 8(2).

Dewantara, B. Y., Iradiratu, D. P. K., Rahmatullah, D., & Winarno, I. (2019). Designing environmentally friendly fishing boats using solar-powered electric motors. Cyclotron, 2(1).

Mandasari, D. R., Sudiarto, B., Amelia, L., & Nandar, C. S. A. (2024). Electric ship propulsion with BLDC IPM motors: Performance and efficiency analysis. National Journal of Electrical Engineering and Information Technology, 13(2).

Mulyanto, R., Soetijono, I. K., Marwiyah, Akbar, S., & Martha, C. P. (2021). Ecotourism-based mangrove conservation strategy at Cemara Beach, Banyuwangi Regency. Journal of Aquaculture Science, 6(Special Issue), 148–156.

Rango, R., Irawan, C., & Sumatupang, L. (2023). Solar-powered boat propulsion system with real-time monitoring. Journal of Applied Science, 9(2).

Sunardi, & Pamungkas, R. S. (2019). Study of small boats with electric drive for the supervision of river and estuary conservation areas. Journal of Marine, 12(1).