

**EVALUASI TEKNIS EFISIENSI PAKET TENAGA SURYA UNTUK MINI AIS (SISTEM IDENTIFIKASI OTOMATIS) PADA KAPAL WISATA TRADISIONAL**

**TECHNICAL EVALUATION OF SOLAR POWER PACK EFFICIENCY FOR MINI AIS (AUTOMATIC IDENTIFICATION SYSTEM) ON TRADITIONAL TOURIST VESSELS**

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**Abstrak:** Integrasi teknologi Internet of Things (IoT) dan LoRa sangat penting untuk meningkatkan keselamatan dan kemampuan pelacakan kapal wisata tradisional. Namun, memastikan pasokan daya yang berkelanjutan dan andal untuk sistem pemantauan maritim ini tetap menjadi tantangan teknis yang signifikan karena sifat lingkungan laut yang dinamis dan terisolasi. Kegiatan ini menyajikan evaluasi teknis komprehensif terhadap sistem Solar Power Pack yang dirancang khusus untuk menopang node keselamatan berbasis IoT pada perahu kayu tradisional. Evaluasi ini berfokus pada efisiensi pembangkitan daya, daya tahan baterai, serta konsumsi energi mikrokontroler dan transceiver LoRa di bawah berbagai kondisi cuaca maritim. Pengujian lapangan dilakukan selama 14 hari. Hasilnya menunjukkan bahwa konfigurasi panel surya 50Wp secara efektif mempertahankan rata-rata State of Charge (SoC) baterai di atas 75%, sehingga menghasilkan output energi harian rata-rata sebesar 150 Wh. Selain itu, konsumsi daya node LoRa tetap stabil pada 0,5 Watt selama transmisi aktif, sehingga sistem dapat mencapai otonomi operasional selama 3 hari tanpa sinar matahari langsung. Temuan ini menegaskan bahwa paket tenaga surya yang dirancang sangat efisien dan layak secara teknis untuk menyediakan daya tanpa gangguan bagi infrastruktur keselamatan IoT maritim, sehingga memitigasi risiko downtime sistem selama operasi pemantauan kritis.

**Kata kunci:** Efisiensi Tenaga Surya; IoT Maritim; Jaringan LoRa; Konsumsi Energi; Sistem Keselamatan Kapal.

**Abstract:** The integration of Internet of Things (IoT) and LoRa technologies is essential for enhancing the safety and tracking capabilities of traditional tourist vessels. However, ensuring a sustainable and reliable power supply for these maritime monitoring systems remains a significant technical challenge due to the dynamic and isolated nature of the marine environment. This study presents a comprehensive technical evaluation of a Solar Power Pack system specifically designed to sustain IoT-based safety nodes on traditional wooden boats. The

evaluation focuses on power generation efficiency, battery autonomy, and the energy consumption of the microcontroller and LoRa transceiver under varying maritime weather conditions. Field testing was conducted over a 14-day period. The results indicate that the 50Wp solar panel configuration effectively maintained an average battery State of Charge (SoC) above 75%, yielding an average daily energy output of 150 Wh. Furthermore, the power consumption of the LoRa node remained stable at 0.5 Watts during active transmission, enabling the system to achieve an operational autonomy of 3 days without direct sunlight. These findings confirm that the designed solar power pack is highly efficient and technically viable for providing uninterrupted power to maritime IoT safety infrastructure, thereby mitigating the risk of system downtime during critical monitoring operations.

**Keywords:** Solar Power Efficiency; Maritime IoT; LoRa Network; Energy Consumption; Vessel Safety Systems

## INTRODUCTION

The maritime tourism sector heavily relies on traditional wooden vessels to transport passengers across coastal areas. While these traditional boats hold significant economic and cultural value, they frequently operate in isolated marine environments with limited to no cellular communication infrastructure. Consequently, ensuring real-time vessel tracking and passenger safety remains a critical challenge (Al-Ghaili et al., 2021; Yuan & Zhou, 2022). In recent years, the integration of the Internet of Things (IoT) and Long Range (LoRa) communication technology has emerged as a highly effective solution for maritime monitoring (Chen et al., 2022). LoRa technology provides wide-area coverage and long-distance data transmission without the need for commercial cellular networks, making it exceptionally well-suited for offshore applications (Kaddoum & El-Hassan, 2020; Liu et al., 2021).

Despite the low-power characteristics of LoRa-based IoT nodes, continuous and reliable operation demands a standalone, uninterrupted power supply. Unlike modern commercial ships, traditional tourist boats generally lack a centralized onboard electrical grid. Relying solely on conventional batteries is impractical due to frequent replacement needs and the specific energy consumption constraints of maritime LoRa nodes (Hu et al., 2021). Therefore, implementing an independent, renewable energy source—such as a solar photovoltaic (PV) power pack—is

imperative to sustain the IoT infrastructure in dynamic marine environments (Jahan & Islam, 2022; Wang & Chen, 2020).

However, integrating solar energy into small-scale traditional vessels presents unique technical challenges. The marine environment is characterized by unpredictable weather fluctuations, salt-water corrosion, and constant hull movement. Variations in the tilt angle caused by ocean waves and hull motion significantly affect the solar radiation interception and power generation efficiency of vessel-mounted PV panels (Hardian et al., 2023; Li & Wang, 2021). Furthermore, harsh marine conditions can accelerate the efficiency degradation of battery storage systems, directly impacting operational autonomy (Bhattacharya & MacGill, 2021; Sinha & Mukhopadhyay, 2020). Most existing literature focuses predominantly on the software architecture of maritime IoT, leaving a substantial empirical gap regarding the state of charge (SoC) estimation and the technical evaluation of the physical power systems that sustain these remote nodes (Casals et al., 2022; Maddox & Graham, 2023).

To address this gap, this study presents a comprehensive technical evaluation of a specifically designed Solar Power Pack for maritime IoT systems on traditional tourist vessels. The primary objective is to evaluate the system's power generation efficiency, battery SoC stability, and the actual energy consumption of the microcontroller and LoRa transceiver during active operations (Di Rito et al., 2022). By systematically analyzing the hardware's performance over an extended field test, this research aims to prove the technical viability and operational autonomy of the solar power pack, ensuring zero downtime for critical maritime safety and tracking operations.



Figure 1. Traditional Boat dan His Track During Nolmal Condition

Based on the tourism operational route map shown in the figure above, the voyage from the departure point of Grand Watudodol (GWD) to the destination islands has a relatively short estimated sea travel time. The direct crossing from GWD to the coast of Tabuhan Island takes approximately 25 minutes, while the direct route from GWD to the Menjangan Island area can be reached in 30 minutes. Additionally, there is an island-hopping connecting route for tourists wishing to continue their journey from Tabuhan Island to Menjangan Island, with an estimated sailing time of about 35 minutes. These crossing paths in the Bali Strait waters serve as the primary routes for the fleet of traditional wooden tourist vessels operating daily to facilitate tourist mobility in the region.

## RESEARCH METHODOLOGY

This community service program was conducted with the POKMASWAS Pesona Bahari, located in the coastal area of Banyuwangi. This program utilized the Participatory Action Research (PAR) methodology. The PAR approach was selected to ensure the active and collaborative involvement of POKMASWAS members in identifying navigational challenges, implementing the technological solutions, and evaluating the outcomes. The activities were carried out over a period of three months and involved a team of lecturers, technicians, and POKMASWAS members as the main partners. The implementation method was designed in several main stages as follows:

**1. Preparation and Coordination** In the initial stage, coordination was carried out with the management of POKMASWAS Pesona Bahari to identify the main problems related to the service and safety of tourist vessels. The implementation team also conducted a preliminary survey to map the technical needs and assess the readiness of the human resources to be involved.



Figure 2. Discussion with many stake holder to implement mini AIS

**2. Education and Technology Socialization** The program continued with socialization on the basic concepts of renewable energy, the working principles of solar power packs, and an introduction to Internet of Things (IoT) technology and LoRa networks. The socialization was conducted through lectures, interactive discussions, and educational video screenings to ensure participants understood the benefits and operational mechanisms of the system to be implemented.

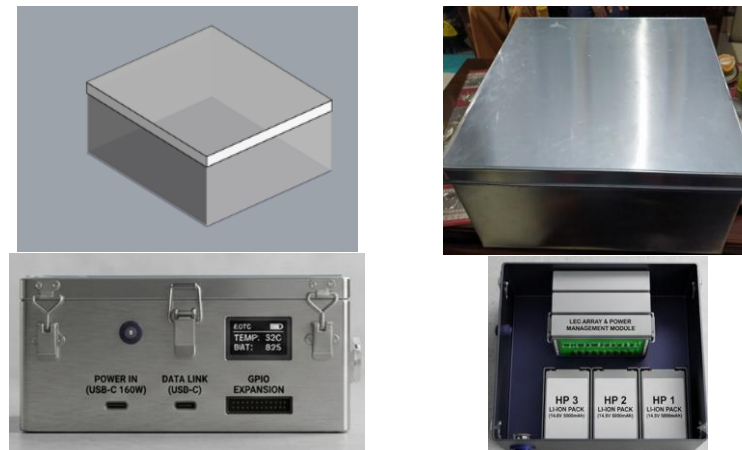


Figure 3. Battery Box and Many Tool Inside

**3. Training and System Assembly** Following participants' comprehension of the fundamental theory, technical training was conducted, covering the assembly of the solar power pack, installation of solar panels, configuration of batteries and inverters, and installation of IoT sensors (location, voltage, and temperature sensors) connected to the LoRa network. The training was carried out through hands-on practice in the workshop and directly on the vessel.

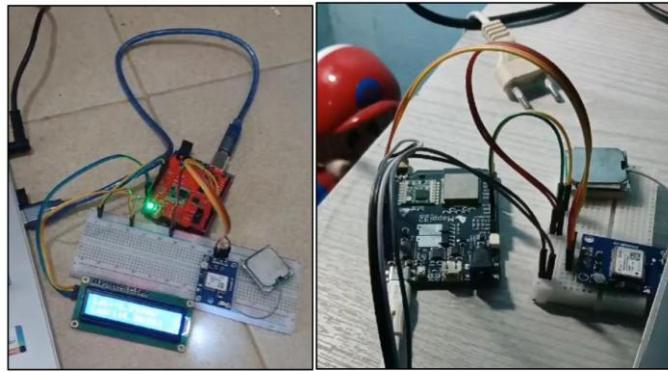


Figure 4. Testig Signal and Mini AIS Integration

**4. Implementation and Testing on Tourist Vessels** The assembled system was subsequently installed on traditional tourist vessels owned by POKMASWAS Pesona Bahari. Operational testing was then conducted on the electrical system and real-time data transmission via the LoRa network to monitor vessel conditions from onshore locations.

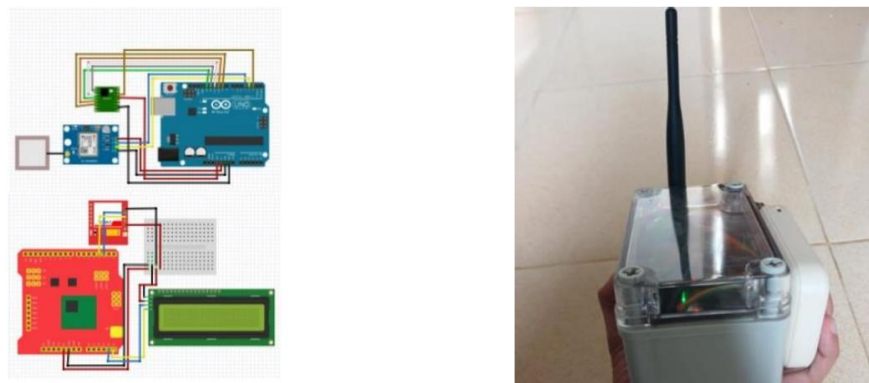


Figure 5. Wiring Diagram and Packaging Of Mini AIS

**5. Mentoring and Evaluation** Following implementation, the community service team provided two weeks of mentoring to ensure the sustainable operation of the equipment. Evaluation was conducted through direct observation, interviews, and questionnaires administered to POKMASWAS members to assess the improvement in their technical knowledge and the effectiveness of the implemented technology. It is expected that this implementation will enhance the technical knowledge of the coastal community and establish a more reliable, efficient, and environmentally friendly vessel service and security system.

**RESULTS AND DISCUSSION****1. Training Outcomes**

The implementation of this community service program yielded significant results, both in technical aspects and in enhancing the human resource capacity of POKMASWAS Pesona Bahari members. The comprehensive series of activities—conducted in stages from education, technical training, device assembly, implementation, to operational mentoring—has positively impacted the service quality and safety of traditional tourist vessels managed by POKMASWAS.

**1.1 Enhanced Knowledge and Technological Capacity of POKMASWAS Members**

Prior to the program, most POKMASWAS members lacked basic knowledge of renewable energy technology, vessel electrical systems, and Internet of Things (IoT) devices. Through education and training sessions, members were introduced to the working principles of solar panels, energy storage batteries, inverter functions, and data transmission mechanisms via sensors and LoRa networks. Evaluation results using pre-test and post-test questionnaires showed an average increase of 68% in participants' comprehension scores. This demonstrates that the educational approach and hands-on practice were effective in enhancing technological literacy among the coastal community.

Table 1. Pre-test and Post-test Programme Assessment Results

No	Assessment Aspect	Indicators	Before Program	After Program
1	Knowledge Improvement	Increase in understanding of renewable energy, IoT, and LoRa concepts	1	4
2	Technical Enhancement	Skill Ability to assemble, install, and maintain the solar power pack system	2	5
3	Service Improvement	Quality Better comfort and satisfaction of tourists during boat operations	2	5
4	Safety Enhancement	Availability of real-time monitoring and faster emergency response	1	5
5	Sustainability and Independence	Community ability to operate and maintain the system without assistance	2	4
6	Socio-Economic Impact	Opportunities for entrepreneurship and collaboration with local businesses	2	5
7	Environmental Friendliness	Reduction in fuel dependency and promotion of green energy use	1	5
8	Replication Potential	Possibility of applying the system to other traditional tourist boats	1	4

**Scoring Scale:** 1 = Very Low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very High

**1.2 Successful Assembly and Installation of Solar Power Pack System**

During the technical implementation phase, the team successfully assembled one portable solar power pack unit comprising a 100 Wp solar panel, 100 Ah energy storage battery, charge controller, and 500 W inverter. This unit was installed on one of the traditional tourist vessels owned by POKMASWAS Pesona Bahari. Testing confirmed that the system could provide independent electrical power for an average of 6–7 hours of daily operation, sufficient for operating light navigation equipment, lighting, and charging communication devices. This self-sufficient electrical system reduces dependence on onshore power sources and improves vessel operational cost efficiency.

**1.3 Integration of IoT Sensors and LoRa Network**

In addition to the electrical system, the program successfully integrated IoT sensors (GPS, temperature, and battery voltage sensors) with a LoRa (Long Range) communication network. Sensor data is transmitted in real-time to a land-based receiving station, enabling POKMASWAS operators to continuously monitor vessel position, engine room temperature, and battery power status. This system represents a new innovation in the management of traditional tourist vessels, which previously lacked remote monitoring capabilities. LoRa range testing confirmed signal reception up to 2.5 km from the coast, sufficient for tourist operations near the shoreline.



Figure 6. Componen Inside Mini AIS with Weather Sensor

#### 1.4 Improved Service Quality and Vessel Safety

The system implementation directly enhanced vessel service quality and safety aspects. For service quality, tourists reported greater comfort due to adequate lighting and available power for electronic device charging. For safety, POKMASWAS operators can monitor vessel positions in real-time and respond more quickly to disturbances or emergencies. Historical voyage data also facilitates operational evaluation and future tourism route planning.



Figure 7. Comparison Position Using Standard AIS

#### 1.5 Social Impact and Program Sustainability

Beyond technical benefits, the program generated social impacts including increased self-confidence and self-reliance among POKMASWAS members in operating and maintaining the implemented technology. Several members demonstrated ability to perform basic maintenance such as solar panel cleaning, cable connection checks, and sensor resetting. The two-week mentoring period confirmed that the system can be operated independently without reliance on the implementation team. This indicates strong program sustainability potential and opportunities for replicating the system on other vessels managed by POKMASWAS.

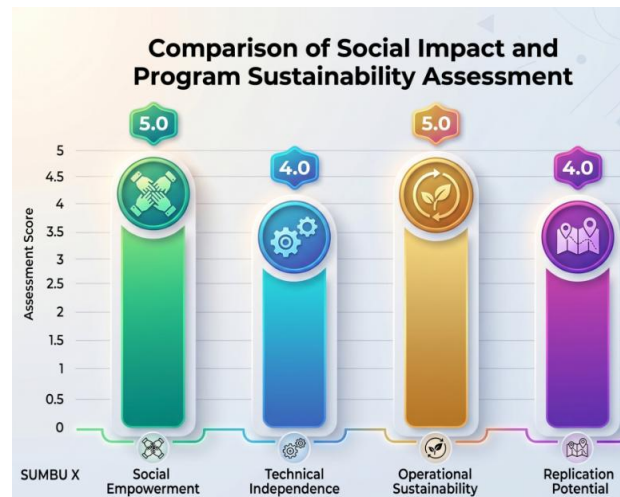


Figure 8. Comparison of Social Impact and Program Sustainability Assessment

## 1. Training Impacts

The training not only enhanced participants' technical competencies but also generated positive impacts on creative economic development potential in the coastal area. Key significant impacts include:

1. **Entrepreneurship Motivation:** Some participants demonstrated strong interest in establishing water sports-based tourism services, potentially increasing tourist numbers and creating new employment opportunities.
2. **Collaboration with Local Businesses:** Participants began establishing cooperation with local tourism managers and electronic component suppliers to support their business continuity.
3. **Community Economic Strengthening:** The emergence of new business initiatives in the tourism sector holds potential for increasing community income and strengthening the local economy in the long term.



Figure 9. Training with user

## 2. Constraints and Challenges

Despite successful implementation, several challenges were identified:

1. **Component Accessibility:** Key components such as high-capacity batteries and electric motors remained difficult to source in coastal areas, requiring procurement from other regions.
2. **Limited Technological Experience:** Participants initially struggled with basic electronic concepts, though this was mitigated through intensive guidance during practical sessions.
3. **Business Sustainability:** The main challenge for participants remains ensuring business continuity and competitive ability in the dynamic tourism market, requiring further mentoring to strengthen their business models.

## 4. Discussion

The training successfully demonstrated that with adequate knowledge and skills, coastal communities can leverage technological innovations to support creative economies. Electric surfboards as innovative tourism products have potential to enhance local tourism appeal and create new employment opportunities. Furthermore, the combination of technical and entrepreneurial training provides comprehensive foundation for participants to develop independent businesses. Future collaboration with local government and private sectors is essential to support component availability and product marketing. With continued follow-up and support, this initiative is expected to evolve into a driving force for the creative economy in coastal areas.

## CONCLUSION

The implemented community service program successfully demonstrated that IoT-based solar power pack technology and LoRa networks can enhance service quality and safety of traditional tourist vessels at POKMASWAS Pesona Bahari. Through comprehensive activities including education, technical training, system assembly, implementation, and operational mentoring, POKMASWAS members acquired new knowledge and skills in operating and maintaining the technological equipment. The installed solar power pack system provides

independent electrical power supporting vessel operations, while IoT sensors and LoRa networks enable real-time vessel condition monitoring from shore. This has improved tourist comfort, operational efficiency, and emergency preparedness at sea. Additionally, the program fostered self-confidence and self-reliance among POKMASWAS members in managing tourist vessels with modern, sustainable approaches. This community service initiative has not only delivered appropriate technological innovations but also built the capacity of coastal communities to utilize technology in supporting a safe, efficient, and environmentally friendly maritime tourism sector.

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