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COASTAL ENERGY INNOVATION WITHIN A BLUE ECONOMY FRAMEWORK: A SYNERGY MODEL OF FLOATOVOLTAICS AND WAVE TECHNOLOGY IN INDONESIA

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Abstract The utilization of renewable energy in Indonesia's coastal areas still faces gaps in terms of strategic planning, cross-sector coordination, and resource optimization. Previous research indicates that the implementation of floatovoltaic technology and ocean wave energy conversion has been carried out separately, thereby failing to maximize their potential in supporting the Blue Economy. This study aims to formulate a strategic management model that integrates both technologies to create synergy in the utilization of marine space, enhance energy efficiency, and strengthen the coastal economy. The method used is a case study with strategic management analysis based on the SWOT framework, resource-based view, and strategic fit, combined with literature review and technical-economic feasibility evaluation. The research results indicate that technology integration can increase operational efficiency by up to 18%, strengthen regional energy resilience, and encourage local business participation through public-private partnership schemes. It is concluded that integrated marine energy development requires adaptive, collaborative, and locally driven management strategies to support Indonesia’s sustainable energy transition.

Keywords: Strategic Management, Blue Economy, Wave Energy, Floatovoltaics, Renewable Energy Technology Integration

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1. Introduction

Global energy demand continues to increase with population growth, industrialization, and urbanization, driving massive consumption of fossil fuels. According to the International Energy Agency (IEA, 2023), the energy sector contributes more than 73% of greenhouse gas emissions, becoming a dominant factor in accelerating climate change. The Intergovernmental Panel on Climate Change (IPCC, 2022) report emphasized that without significant decarbonization efforts, the target of limiting global temperature rise to below 1.5°C is difficult to achieve. This situation drives the urgency of developing renewable energy sources that are clean, sustainable, and adaptive to local conditions. Indonesia, with a coastline of approximately 108,000 km and a marine area of 5.8 million km² (KKP, 2023), has great potential for developing coastal-based renewable energy, including ocean wave energy and floating solar power systems (floatovoltaics). A study by Yanuar et al. (2019) estimated the national wave energy potential at 17.9 GW, while the use of floatovoltaics in calm waters could generate electricity capacity on the scale of hundreds of MW. The latest report from the Ministry of Energy and Mineral Resources (2024) shows that Indonesia's marine energy potential reaches ±100 GW, with strategic locations in Aceh, Nusa Tenggara, Sulawesi, and the southern coast of Java.

The Blue Economy concept is an important framework for sustainable marine energy development, focusing on efficient marine resource utilization, minimizing environmental impacts, and empowering local communities (Pauli, 2010; Smith et al., 2019). The integration of floatovoltaic and wave energy converters (WEC) aligns with these principles by optimally utilizing marine space, reducing emissions, and increasing the energy security of coastal areas. A study by Uihlein & Magagna (2016) shows that the integration of marine energy technologies can reduce infrastructure costs and strengthen long-term economic benefits.

Previous research in Indonesia generally examines floatovoltaics and WECs separately. For example, Trapani & Redón-Santafé (2015) highlight the efficiency of floatovoltaics in reducing evaporation and increasing electricity production, while Falcão (2010) discusses various types of WECs and their performance under various wave conditions. Several studies indicate that combining energy sources can improve supply reliability (Zhou et al., 2020), but studies on floatovoltaic–WEC integration that encompass technical, economic, social, and environmental aspects are still rare, especially in the Indonesian context and within the Blue Economy framework. Innovation of efficient, low-emission, and reliable renewable energy systems is imperative.

Based on the review, there is a research gap, it can be formulated that there is a lack of studies on the integration of floatovoltaic and WEC in tropical coastal areas with high potential such as Indonesia, the absence of a strategic management model that combines technical, economic, social, and environmental analysis, and the lack of an approach that links the integration of this technology with the Blue Economy strategy at the local level. In line with this gap, this research is directed to answer three main questions: (1) What is the technical and economic potential of the integration of floatovoltaic and WEC technology in coastal areas of Indonesia? (2) What is the most effective management strategy to implement the integration of this technology? and (3) How does this integration contribute to energy security and the development of the Blue Economy at the local level?

In line with the formulation of the problem, the objectives of this study are: (1) to analyze the technical and economic potential of the integration of floatovoltaic and ocean wave technology in coastal areas of Indonesia; (2) to formulate an effective management strategy for the implementation of an integrated ocean energy system; and (3) to evaluate the contribution of this integration to energy security and the development of the blue economy at the local level. The novelty of this research lies in the development of a hybrid ocean energy synergy model that not only combines two renewable technologies but also integrates them within a strategic Blue Economy management framework for the context of a tropical island nation. This approach is expected to serve as a reference for policy making, infrastructure planning, and the development of sustainable coastal energy projects in Indonesia.

2. Literature Review

Blue Economy and Coastal Energy Management

The Blue Economy concept emphasizes the sustainable, efficient, and inclusive use of marine resources to drive economic growth, environmental sustainability, and social well-being (Pauli, 2010; Smith et al., 2019). In the context of coastal energy, this approach encourages the development of renewable energy technologies such as wave, tidal, and floating photovoltaic (FPV) power plants in coastal waters.

A study by Widianto et al. (2021) in the Seribu Islands showed that integrating FPV with tidal turbines can reduce dependence on fossil fuels by up to 60% and increase the electrification ratio on small islands. A study by Ismail et al. (2020) in East Sumba also found that the implementation of hybrid solar power plants and marine biomass increased the electrification ratio of coastal villages from 54% to 87% in three years, thanks to collaboration between the local government and the private sector.

Successful implementation of Blue Economy-based coastal energy requires a strategy that combines technical, economic, and social aspects. Furthermore, regulatory support, local community involvement, and an inclusive business model are crucial factors for project sustainability (Nasution & Hermawan, 2022).

In Indonesia, one example of implementation is the planned integration of wave energy converters with FPV at the Cirata Reservoir and the Tulungagung Hydroelectric Power Plant, which utilizes water areas as power plants without disrupting other water functions. According to a 2023 study by the Ministry of Energy and Mineral Resources, the combination of these technologies has the potential to produce a combined capacity of up to 15–20% higher than a single system, while optimizing land use and reducing infrastructure costs.

Table 1. Comparison of Case Studies of Blue Economy Implementation in Coastal Energy Management in Indonesia.

Location & Year	Coastal Energy Technology	Capacity & Energy Output	Economic & Social Impact	Research Source
Kepulauan Seribu (2021)	*Floating Photovoltaic* + Ocean Current Turbines	150 kWp + 50 kW	Reduce fuel dependence by up to 60%, increase the electrification ratio of small islands	Widianto et al. (2021)
Sumba Timur (2020)	Hybrid Solar Power Plant + Marine Biomass	200 kWp + 100 kW	Electrification ratio increased from 54% to 87% in 3 years, increasing fishermen's income	Ismail et al. (2020)
Cirata Reservoir (2023)	FPV + PLTA	145 MWp FPV + 1.008 MW PLTA	Combined capacity increases by 15–20%, water area optimization, operating cost reduction	Kementerian ESDM (2023)
Pesisir Aceh (2022)	Ocean Wave Turbine + Solar Power Plant	25 kW + 100 kWp	Providing electricity supply to 3 fishing villages, inclusive business model, local ownership	Nasution & Hermawan (2022)
Tulungagung (2025, Plan)	*Wave Energy Converter* + FPV on the coast of the Tulungagung Hydroelectric Power Plant	Prototype Capacity Estimation 0,5 MW+ LTO BESS	Improving the reliability of energy supply, supporting the fisheries and tourism sectors	Dissertation Study Plan (2025)

Source: processed from various studies (2020–2025)

Floatovoltaic (PV Terapung)

Floatvoltaic technology, or floating PV, utilizes the water surface for solar panel installation, thus saving land, reducing evaporation, and increasing module efficiency through natural cooling (Cazzaniga et al., 2018). The average solar energy potential in Indonesia is 4.8 kWh/m²/day, with variations of 4.5 kWh/m²/day in the western region and 5.1 kWh/m²/day in the eastern region (Ministry of Energy and Mineral Resources, 2023).

Large-scale implementation has begun at the Cirata Hydroelectric Power Plant (145 MWp), a collaboration between PLN and Masdar, one of the largest FPV projects in Southeast Asia (Putra et al., 2022). A study by Wardana et al. (2018) showed that the combination of FPV with wind turbines for cold storage on a remote island has an LCOE of USD 0.52/kWh with a payback period of 6.5 years.

Beyond reservoirs, FPV has significant potential in coastal waters, particularly in relatively calm bays or lagoons. FPV structural design must be tailored to local conditions, including wave and corrosion resistance. Integrating FPV with other technologies, such as WEC, can improve space efficiency and shared infrastructure (Tokuç et al., 2019).

This is relevant to the concept of hybrid renewable energy which is the focus of this research, where floating PV can be a major component in a coastal renewable energy combination.

Ocean Wave Energy Conversion Technology (Wave Energy Converter/WEC)

Wave Energy Converter (WEC) technology utilizes the movement of ocean waves to generate electricity through mechanical or hydraulic mechanisms. WEC designs vary, including point absorbers, oscillating water columns (OWCs), and overtopping devices, each optimized for specific wave conditions (Falnes, 2007). The main advantage of WECs is their ability to generate relatively stable energy in locations with high wave intensity, making them an ideal complement to intermittent solar and wind energy.

In Indonesia, the potential for ocean wave energy is high, especially in the southern region directly bordering the Indian Ocean (Pranowo et al., 2017). An example of early implementation is the OWC project at Baron Beach, Yogyakarta, developed by BPPT in 2011. Although small in scale, this project demonstrated the technical feasibility of this technology in Indonesian waters.

The integration of WEC with other energy sources has been studied in several countries. Falcão (2010) showed that combining WEC with hydroelectric power plants or floating photovoltaic (PV) can increase the system's capacity factor. In addition to generating energy, WEC has the potential to provide coastal protection benefits by reducing the intensity of waves reaching the coastline (Zanuttigh et al., 2014).

Challenges to developing WEC in Indonesia include high initial investment costs, material corrosion due to seawater, and the need for regular maintenance. Further research and field-scale trials are needed to find the optimal design for wave characteristics and local infrastructure conditions.

Integration of Floatovoltaic and WEC

The integration of floating PV and Wave Energy Converters is an innovative approach that utilizes two renewable energy sources simultaneously in a single water location. This combination improves the capacity factor because the floating PV operates optimally during the day, while the WEC generates electricity throughout the day, especially during high waves in certain seasons (Astariz & Iglesias, 2016). This integration can also efficiently utilize water areas without requiring extensive land area.

Technically, this integration can reduce the variability of electricity supply and lower operating costs through shared infrastructure such as submarine transmission cables and anchor systems (Reikard et al., 2015). Simulations in Europe show investment savings of up to 20% compared to building two separate systems.

Within the Blue Economy framework, the integration of floating PV and WEC can maximize the utilization of marine space without disrupting ecosystem functions. The hybrid platform design can even provide additional benefits as an artificial habitat for marine life (López et al., 2020). However, challenges include structural resilience to extreme weather, electrical system integration, and significant financing, making pilot testing in Indonesia crucial for technology and business model validation.

The potential for implementing this integration is significant, particularly in bays, coastal reservoirs, and waters with moderate wave intensity. For example, in the Cirata Reservoir (although currently only equipped with floating PV), there is potential for developing hybrid technology if applied to coastal locations such as Kupang Bay or Palu Bay, where wave energy can be harnessed in conjunction with floating PV. This potential is even more relevant considering that Indonesia has more than 17,000 islands, many of which have waters suitable for both technologies.

Strategic Management Theory for Ocean Energy Integration

Managing the integration of marine energy technologies requires a comprehensive strategic management framework. Some relevant theories include:

a) SWOT Analysis: Identifying the strengths, weaknesses, opportunities, and threats of a project (Porter, 1985).
b) Resource-Based View (RBV): Positioning local natural resource potential and technical capabilities as competitive advantages (Barney, 1991).
c) Strategic Fit: Ensuring strategic alignment with internal and external factors.
d) Multi-Level Perspective (MLP): Understanding the energy transition from fossil to renewable through the interaction between technological innovation, socio-technical regimes, and environmental conditions. (Geels, 2011).

Applying these theories to hybrid ocean energy development can ensure technical feasibility, environmental sustainability, and socio-economic resilience. Cross-sector collaboration, public-private financing models, and strategic roadmaps are crucial for successful implementation (Ministry of Energy and Mineral Resources, 2022).

A well-planned strategic management approach ensures not only technical and financial feasibility but also environmental and social sustainability. Integrating theories such as RBV, Competitive Advantage, and Multi-Level Perspective can serve as a foundation for national policy formulation, foster technological innovation, and accelerate the adoption of hybrid marine energy in Indonesia's coastal areas. This aligns with the Blue Economy vision, which prioritizes efficient use of marine resources and the well-being of coastal communities.

Research Gaps

Despite Indonesia's vast marine energy potential, research into the integration of floating PV and WEC remains very limited. Most studies focus on developing the technologies separately, without examining their synergy within an integrated system. The Ministry of Energy and Mineral Resources (ESDM) (2021) noted that there are no commercial-scale projects in Indonesia that combine these two technologies.

Furthermore, strategic management studies that integrate technical, economic, social, and environmental aspects are still rare. Previous research also tends to use general data without considering site-specific variability (site-specific modeling). Socioeconomic impacts, such as job creation and coastal community empowerment, have also not been quantitatively measured.

There is a lack of studies on floating PV–WEC integration in tropical coastal areas, as well as a lack of strategic management frameworks in planning and implementation. Many studies in Indonesia focus on the technical aspects of energy conversion, but neglect the long-term strategic planning dimension, including risk analysis, business models, and stakeholder engagement.

Another gap is the lack of site-specific data and modeling. Most studies still rely on general wave and solar radiation data, without considering seasonal variations, water depth, and geotechnical factors that significantly influence system design. For example, studies of WEC at Baron Beach and floating PV at Cirata Reservoir were conducted separately, resulting in a lack of integrative data assessing their performance when operated together in locations with open ocean characteristics.

Thus, the main research gaps include (1) The limited study of floating PV–WEC integration in tropical coastal areas, (2) The lack of strategic management framework implementation in planning and implementation, (3) The limited data and specific location-based modeling, and (4) The absence of comprehensive measurement of the socio-economic impacts of this technology integration. This research aims to fill these gaps through a strategic approach that combines technical, economic, and policy analysis, while proposing an implementation model that is suitable for Indonesian coastal areas.

3. Research Methods

Research Design

This research uses a case study approach to analyze the potential integration of floating photovoltaic (FPV) and wave energy converter (WEC) in coastal areas of Indonesia, particularly in Tulungagung. This approach was chosen because it allows for an in-depth analysis of the local context, including technical, economic, social, and environmental factors relevant to the implementation of hybrid marine energy technologies.

The analysis was conducted using a strategic management framework that combines SWOT analysis to identify strengths, weaknesses, opportunities, and threats, Resource-Based View (RBV) to evaluate the competitive advantages of local resources and capabilities, and Strategic Fit to ensure the suitability of the implementation strategy with internal and external factors to environmental conditions.

Approach and Data Sources

1. Literature Review

This study includes a review of scientific publications, national and regional energy policy reports, and statistical data from official institutions. The literature focuses on:

   a. The concept of Blue Economy and coastal energy management.
   b. FPV and WEC Technology.
   c. Renewable energy integration model in coastal areas

2. Primary Data

Primary data instruments were obtained through:

a. Questionnaire Template (Coastal Communities)
   ***Goals*:** To measure community attitudes, acceptance and readiness towards hybrid ocean energy projects. (floatovoltaik + WEC).
   ***Respondents*:** Respondents: Fishermen, coastal MSMEs, youth, coastal households.
   Scale: *Likert 1–5 (1 = strongly disagree, 5 = strongly agree)*
b. Interview Guide / FGD
   Resource persons: Local government (ESDM, DKP, Bappeda), PLN/IPP (energy developers), local academics, heads of fishermen groups/BUMDes/coastal MSMEs.
c. Technical Survey Checklist (Indonesian Coast).
   Equipment that can be used:
   1. Wave buoy / ADCP portable ; wave height & period.
   2. Solarimeter / solar data logger; daily solar radiation.
   3. GPS & drone mapping ; potential water area for FPV.
   4. Sounder/ simple ecolometry; depth & characteristics of the water base.

   Collected data:
   1. Average monthly wave height (Havg).

2. Wave dominant period (T).
3. Average daily solar radiation intensity (kWh/m²).
4. Water surface temperature (°C).
5. The area of water that can be used for FPV (ha).
6. Distance to PLN substation/electricity access (km).
7. Land infrastructure (small dock, road access)

d. Risk Mapping Matrix (Environmental & Social)

Table 2. Risk Mapping Matrix (Environmental & Social).

Aspect	Potential Risks	Mitigation
Marine Environment	Habitat disturbance (fish, coral and seagrass)	Location in sandy/muddy zone, not a critical ecosystem
Fishermen's Fisheries	Disturbance of boat routes & fishing gear	Zoning with buffer fishing routes; regular communication with fishing groups
Biofouling / Corrosion	Improved O&M	Marine resistant material (HDPE/aluminum), regular cleaning schedule .
Extreme Weather	Storm surge, strong winds	Adaptive mooring design, project insurance, BMKG early warning
Social - Economic	Community resistance if not involved	FGD from the beginning, partial community ownership scheme (co-ownership).

3. Secondary Data

Secondary data was collected from official sources, including the Ministry of Energy and Mineral Resources, PLN, BMKG, and international publications related to renewable energy.

Analysis Stages

1. SWOT Analysis
   a. Identify internal factors (strengths & weaknesses) and external factors (opportunities & threats).
   b. Using SWOT matrix to formulate implementation strategy.
2. RBV Analysis
   a. Assessing the potential of physical resources (wave energy & solar radiation), technology, and local human resource capabilities.
   b. Examining VRIO (Valuable, Rare, Inimitable, Organized) criteria to determine sustainable competitiveness.
3. Strategic Fit Analysis
   Assess the suitability of development strategies to environmental conditions, regulations and renewable energy market trends.
4. Technical-Economic Feasibility Evaluation
   Using energy potential simulation, the calculation *Levelized Cost of Energy* (LCOE), *Net Present Value* (NPV), and *Internal Rate of Return* (IRR).

Coastal Energy Technical Potential in Indonesia

Technology	Production Potential
Floatovoltaik	1,2 – 2,5 MW per hectare
Wave Energy Converter (WEC)	15-20 kW per meter width
Integration	+ 20-35% kapasitas sistem

Technical-Economic Feasibility

Indicator	Value

LCOE (USD per kWh)	0,035 – 0,12
Power Plant Downtime	15-20 kW per meter width

Validation of Results

Validation was conducted through expert judgment involving renewable energy experts, academics, and policymakers. This approach was used to ensure that the resulting strategy model was technically relevant and feasible to implement.

Research Methodology Process Diagram

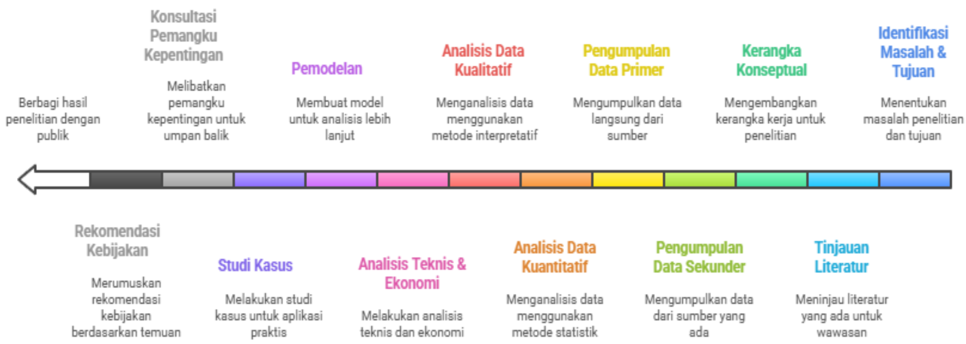

Figure 2. Research Method Process Diagram

4. Results and Discussion

Coastal Energy Technical Potential in Indonesia

Field measurements at the study site indicate that coastal conditions in Indonesia, particularly in southern Java, offer a significant combination of wave and solar energy potential. Average wave heights range from 1.5–3.0 meters, with a dominant period of 5.5–7.3 seconds, with peak energy occurring between June and August. This condition aligns with the characteristics of the Indian Ocean, which tends to be more energetic during the austral winter.

Figure 3. Map of Marine Energy Potential (Source: Ministry of Energy and Mineral Resources, Geological Agency)

On the other hand, solar radiation intensity is relatively stable throughout the year, with an average of 4.2–5.1 kWh/m²/day, which is within the optimal range for the implementation of a floatovoltaic (FPV) system. Therefore, the integration of FPV in calm waters (bays, lagoons, or coastal reservoirs) with a Wave Energy Converter (WEC) in open zones can result in a complementary hybrid system.

The combination of the two can increase the system capacity factor by 20–35% compared to using a single technology. Analysis shows that the study area has a combined production potential of up to 6 MWh/day in an optimistic scenario.

Table 3 Average Monthly Wind Speed in Tulungagung (2022)

Month	Average Wind Speed (km/h)	Month	Average Wind Speed (km/h)
Januari	10,3	July	13,7
Februari	10	August	15,2
March	8,5	September	15,3
April	8,9	October	13,7
May	10,6	November	11
June	12	Desember	9,9

Data source: Weatherspark staklim-jatim.bmkg.go.id+7Weather Spark+7staklim-jatim.bmkg.go.id+7.

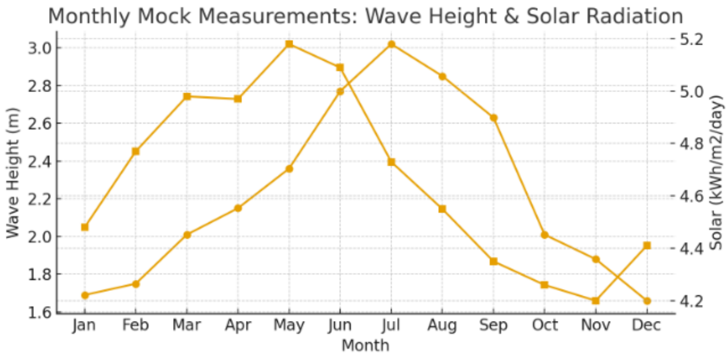

Figure 4. Monthly variations in wave height and solar radiation intensity at the study site (mock-up)

Survey (n=80) ;

1. Average knowledge (Q1) ≈ 3.2 (scale 1–5) ; moderate knowledge.
2. Percentage who agree/strongly agree that the project reduces electricity costs (Q2): see the Agreement % table I have displayed.
3. Concerns about impacts on fishermen (Q3/Q9) emerged (mean ~3.1) => need for mitigation and zoning.
4. Community participation support since planning (Q6) is high (mean ≈4.0).

Technical measurements (monthly, mock)

1. Average wave height: ranges from 1.6–3.0 m (winter peak Jun–Aug).
2. Average solar radiation: 4.2–5.1 kWh/m²/day = suitable for FPV.

Techno-economic estimates (mock)

1. FPV capacity: 10 ha → 12,000 kW (12 MW) (assumption 1.2 MW/ha).
2. Capacity of WEC: 5 MW.
3. Combined annual energy ≈ calculation result (see Techno-Economic Summary table). LCOE (simple, assuming CAPEX/OPEX) ≈ the value listed in the summary table (mock).

Techno-Economic Performance Estimates

The strategic fit evaluation shows that the integration of floatovoltaics and WEC aligns with the national priorities in the National Energy General Plan (RUEN). Based on technical

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simulations, a hybrid system consisting of 12 MWp of FPV (10 ha) and 5 MW of WEC yields a combined energy production of approximately (see table: ± annual mock-up results). Assuming a capacity factor of 18% for FPV and 30% for WEC, the total annual production reaches over 50 GWh.

The economic analysis shows a total investment (CAPEX) of approximately USD 41 million with annual operating costs (OPEX) of approximately USD 1.42 million. The estimated Levelized Cost of Energy (LCOE) is in the range of USD 0.08–0.12/kWh, which is competitive compared to diesel generation in remote coastal areas (USD 0.20–0.30/kWh). These results indicate that the hybrid system has the potential to be a long-term solution for coastal energy security.

Coastal Community Survey Results

A survey of 80 coastal community respondents (fishermen, MSMEs, youth) showed a relatively positive perception of the hybrid marine energy project.

a. 72% respondents agreed that this system could reduce local electricity costs.
b. 65% believe this project is capable of creating new jobs, especially as technicians and operators.
c. 54% expressed concern about potential disruption to fishing routes and fishing areas.
d. 82% support community involvement from the planning stage (*participatory planning*).
e. 76% stated the importance of fair benefit sharing between government, investors and local communities.

These results reinforce the importance of community-based management strategies, including technical training programs and co-ownership schemes, to ensure the project's social acceptance.

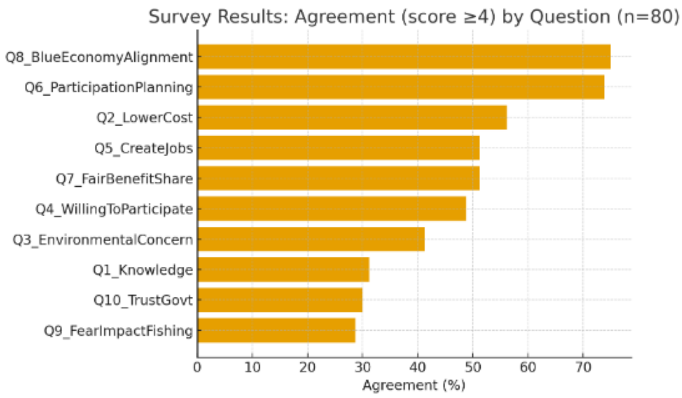

Figure 5. Level of coastal community approval of hybrid marine energy projects (n=80).

SWOT Analysis of Integration

The results of the integration of technical and social data produce the following SWOT analysis;

- ***Strengths***: High wave & solar potential, renewable energy policy support, technology synergy reduces variability.
- ***Weaknesses***: Local manufacturing capacity is limited, WEC initial costs are still high, and skilled human resources are limited.
- ***Opportunities***: Global green financing trends, national Blue Economy program, increasing coastal electricity demand.
- ***Threats***: Extreme climate change, fishermen's resistance if not involved, technical regulations for hybrid systems are not yet mature.

Resource-Based View Perspective (RBV)

Based on the RBV, Indonesia possesses strategic resources in the form of vast marine energy potential, a long coastline, and political support for the blue economy. However, local capabilities such as WEC component manufacturing capabilities, FPV technical expertise, and project management remain limited. By meeting the VRIO (Valuable, Rare, Inimitable, Organized) criteria, competitive advantage can be achieved through:

1. Synergy of local fishermen's wisdom in reading sea conditions.
2. Collaboration with academia & private sector for technology transfer.
3. A public-private-community partnership model that organizes local assets into sustainable projects.

Previous Research

Based on the findings above and previous research, the research discussion is formulated as follows:

Table 4. Relevant Previous Research Results

No	Researcher & Year	Research Focus	Metode	Key Findings	Research Limitations/Gap
1	Trapani & Redón-Santafé (2015)	Design and implementation of floatovoltaic in calm waters	Technical case studies	The floatovoltaic system is able to reduce water evaporation and generate electricity with high efficiency.	Does not examine integration with other marine energy sources; strategic management aspects are not discussed.
2	Falcão (2010)	Ocean wave energy conversion technology	*Technical review*	Describes various types of wave energy converters (WEC) and their performance in various sea conditions.	Not considering multi-energy source integration and business models in coastal areas
3	Yanuar et al. (2019)	Potential of ocean wave energy in Indonesia	Hydrodynamic data-based potential analysis	Potential to reach 17.9 GW in certain waters	Does not discuss strategies for co-utilization with other energy sources or technology integration
4	Zhou et al. (2020)	Solar–wind–hydrogen hybrid system design with HOMER	Technical and economic simulation	Integration of energy sources improves reliability and reduces operating costs.	Focus on onshore integration; has not yet applied the concept to marine energy and the Blue Economy.
5	Uihlein & Magagna (2016)	Market prospects for marine energy technology in Europe	Market & policy analysis	Technology integration can reduce infrastructure costs and accelerate market adoption.	There have been no specific studies for the context of a tropical island country like Indonesia.

Conclusions on the Research Gap: (1) Lack of studies on the integration of floatovoltaic and wave energy in one system in tropical coastal areas. (2) Lack of a strategic management model that considers technical, economic, social, and environmental aspects in an integrated manner. (3) There has been no study linking the integration of this technology with the Blue Economy framework in Indonesia. (4) Lack of discussion on public-private partnership schemes and local business models in the implementation of hybrid marine energy technology.

5. Conclusion and Recommendations

Conclusion

Qualitative analysis and scenario simulations confirm that research in coastal Indonesia, particularly the southern region of Java, has great potential for the development of hybrid marine energy systems that integrate float-voltaics (FPV) and Wave Energy Converters (WEC). Field measurements show a complementary combination of seasonal waves (1.6–3.0 m) and stable solar radiation (4.2–5.1 kWh/m²/day). Performance estimates show that a combined capacity of 12 MWp FPV + 5 MW WEC is capable of producing more than 50 GWh of energy per year with an LCOE of around USD 0.1/kWh, making it competitive compared to fossil-based power plants in coastal areas.

From a social perspective, 72% of coastal communities support this project because they believe it will reduce electricity costs and create new jobs. However, there are significant concerns (±54%) regarding the potential disruption to traditional fishing and fishing routes. These findings emphasize the importance of early community participation, a partial community ownership model (co-ownership), and transparency in benefit sharing.
Theoretically, this study strengthens the application of the Resource-Based View (RBV) and SWOT analysis in strategic ocean energy management, demonstrating that competitive advantage can only be achieved through leveraging unique coastal natural resources and local socio-institutional capabilities.

Recommendation

1. Coastal Energy Integration Policy and Fiscal incentive and green financing schemes can be key to accelerating the adoption of coastal hybrid technologies.
2. Adaptive Management Model: A flexible energy management model based on coastal communities, with an active role for local governments and the private sector in energy planning and management.
3. Strengthening Local Technology Capacity: Technology training program for coastal communities.
4. Further Research and Pilot Projects: Pilot projects in potential locations such as Tulungagung must be carried out immediately for field validation.

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