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Blue-Coast Resilience Hub: A Community-Driven Aquaculture and Renewable-Energy Microgrid for Coastal Fisherfolk in CarCanMadCarLan

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ABSTRACT: The study titled “Blue-Coast Resilience Hub: A Community-Driven Aquaculture and Renewable-Energy Microgrid for Coastal Fisherfolk in CarCanMadCarLan” was developed to address energy insecurity, climate vulnerability, and livelihood instability in coastal communities through the integration of renewable-energy technologies and automated aquaculture systems. The system features a hybrid microgrid powered by solar, wind, and hydro resources with intelligent support for real-time monitoring, automated feeding, and GSM-based emergency notifications. A Community-Based Participatory Research approach was employed, including system design, integration, testing, and evaluation. The system utilized Arduino and Raspberry Pi platforms with embedded monitoring algorithms. Results showed improved energy reliability, enhanced aquaculture efficiency, and strengthened disaster preparedness through real-time monitoring and alert mechanisms. The findings confirm that the system is a scalable and sustainable solution for improving coastal resilience and aquaculture productivity.

KEYWORDS: Renewable Energy Microgrid, Aquaculture System, Coastal Resilience, GSM Monitoring, Community-Based Engineering.

I. INTRODUCTION

Coastal communities in CarCanMadCarLan continue to experience significant challenges related to energy poverty, climate vulnerability, and livelihood instability. Many fisherfolk communities depend heavily on traditional fishing activities and diesel-powered energy systems, which are costly, environmentally harmful, and unreliable during extreme weather conditions. Frequent power interruptions negatively affect aquaculture operations, food preservation, and communication systems, reducing productivity and increasing economic vulnerability among coastal residents.



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Recent advancements in renewable-energy microgrids and automated monitoring technologies have encouraged researchers to explore sustainable alternatives for off-grid and coastal communities. According to Castro et al. (2022), hybrid renewable-energy systems combining solar, wind, and battery storage provide reliable and environmentally sustainable energy solutions for isolated communities. Romero et al. (2025) also emphasized that renewable-energy infrastructures improve operational efficiency and strengthen livelihood resilience in fisheries and aquaculture sectors.

Automation technologies further support sustainable coastal operations through real-time monitoring and hazard detection. Gragasin et al. (2024) demonstrated that GSM-integrated smoke detection systems improve disaster preparedness and emergency response efficiency in remote environments. Likewise, Manjusha et al. (2023) highlighted that automated fish-feeding systems significantly improve aquaculture productivity while reducing labor requirements.

Despite these technological developments, many existing systems focus only on individual functions such as energy generation, aquaculture automation, or hazard monitoring independently. Few studies successfully integrate renewable-energy systems, aquaculture support, and disaster-preparedness technologies into a single operational platform specifically designed for coastal fisherfolk communities.

To address these limitations, the present study proposes the Blue-Coast Resilience Hub, an integrated renewable-energy microgrid and automated aquaculture system equipped with real-time monitoring, GSM-based notifications, smoke detection, and automated feeding mechanisms. The study aims to design, develop, and evaluate a sustainable and community-centered solution capable of improving energy reliability, strengthening coastal livelihoods, and enhancing disaster resilience among fisherfolk communities in CarCanMadCarLan.

II. LITERATURE SURVEY

Foreign Related Literature (Hardware Systems)

The increasing need for sustainable energy solutions has motivated researchers to create advanced hardware systems intended for remote and underserved communities. Hu et al. (2024) explained that decentralized renewable-energy infrastructures lessen dependence on conventional power grids while improving energy availability during disasters and power interruptions. Their study emphasized that renewable-energy hardware systems provide dependable and sustainable electricity support for isolated locations.

Automation hardware has also become widely utilized in aquaculture and environmental applications to improve operational management. Manjusha et al. (2023) developed a microcontroller-based automated fish-feeding device designed to enhance feeding efficiency and minimize manual operation within aquaculture facilities. Their findings revealed that embedded automation technologies improve productivity and simplify operational processes in aquaculture systems.



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Local Related Literature (Hardware Systems)

In the Philippines, the demand for reliable and sustainable energy systems has encouraged researchers to explore renewable-energy hardware solutions for remote communities. Castro et al. (2022) introduced hybrid renewable-energy systems as effective alternatives to fuel-based generators commonly used in off-grid areas. Their research demonstrated that integrating multiple renewable-energy sources improves power reliability and supports sustainable community operations.

The development of hazard-detection hardware systems also became an important focus among local researchers. Gragasin et al. (2024) and Baccay (2024) developed GSM-assisted smoke and fire monitoring devices capable of transmitting immediate alerts during emergencies. Their studies highlighted that integrating communication hardware with safety-monitoring systems enhances emergency-response capability and improves community protection.

Foreign Related Literature (Software Systems)

Intelligent software applications have become essential in renewable-energy management because they improve system efficiency and operational monitoring. Castañeda-Arias et al. (2025) stated that automated energy-management software helps regulate renewable-energy performance and maintain operational stability despite environmental variations. Their findings emphasized the significance of intelligent software controls in improving renewable-energy efficiency.

Researchers also investigated software-driven automation systems for aquaculture applications. Susilawati et al. (2023) designed intelligent automation software powered by renewable-energy technologies for aquaculture management. Their study showed that software-controlled systems contribute to sustainable operations by optimizing energy usage and improving aquaculture efficiency in remote environments.

Local Related Literature (Software Systems)

The advancement of intelligent monitoring technologies in the Philippines has encouraged researchers to develop software systems that support sustainable community operations. Salac et al. (2024) emphasized that renewable-energy management software contributes to environmental sustainability and economic development in isolated communities. Their findings revealed that intelligent monitoring systems improve operational performance and strengthen long-term sustainability.

Researchers also explored communication-based software systems for hazard detection and emergency preparedness. Gragasin et al. (2024) explained that GSM-supported monitoring software improves emergency response by enabling real-time notification and hazard reporting. Their study demonstrated that communication-integrated software systems enhance monitoring reliability and disaster-management efficiency.

Foreign Related Studies

Researchers worldwide have continuously explored the integration of renewable-energy technologies and automation systems to improve sustainability and resilience within remote communities. Hu et al. (2024) developed renewable-energy infrastructures intended to strengthen energy reliability and disaster preparedness in isolated locations. Their findings demonstrated that renewable-energy integration improves long-term operational stability and community resilience.

The advancement of automation technologies also encouraged researchers to create intelligent systems for aquaculture management and environmental monitoring. Susilawati et al. (2023) introduced renewable-energy-powered automation platforms equipped with monitoring and operational-control functions for aquaculture applications. Their research revealed that automated systems improve resource management and operational productivity in sustainable aquaculture environments.



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Local Related Studies

In the Philippine context, researchers have increasingly focused on renewable-energy and monitoring technologies that support coastal and off-grid communities. Castro et al. (2022) developed hybrid renewable-energy infrastructures capable of supplying continuous electricity to isolated areas. Their findings demonstrated improved energy management and enhanced operational reliability in remote-community applications.

To improve emergency preparedness and hazard monitoring, Baccay (2024) designed a GSM-based smoke and fire detection system capable of delivering instant warning notifications during emergency situations. Results from the study showed that communication-supported monitoring technologies improve response efficiency and strengthen community safety within remote environments.

Synthesis of the Review

The reviewed literature and related studies demonstrate ongoing developments in renewable-energy infrastructures, intelligent automation, monitoring technologies, and disaster-management systems intended for sustainable community development. Both international and local researchers emphasized the importance of integrating renewable-energy resources, communication technologies, embedded systems, and automation mechanisms to improve efficiency, resilience, and sustainability in remote communities.

Despite these technological advancements, several gaps remain evident in existing systems. Most studies focused only on individual functions such as power generation, monitoring, or aquaculture management without integrating these technologies into a unified community-centered platform. Some systems also lacked sufficient disaster-preparedness and communication capabilities necessary for coastal operations. These limitations support the development of the proposed Blue-Coast Resilience Hub. By combining renewable-energy microgrids, automated aquaculture technologies, GSM-based monitoring systems, and disaster-management mechanisms into one integrated framework, the proposed system offers a more efficient, sustainable, and resilient solution for coastal fisherfolk communities.

III. METHODOLOGY

The study employed a Developmental Research Design guided by a Community-Based Participatory Research approach. This methodology allowed the researchers to systematically design, develop, test, and evaluate the proposed resilience hub while incorporating the actual needs and concerns of coastal fisherfolk communities in CarCanMadCarLan.

The hardware components included solar panels, vertical-axis wind turbines, hydro-generators, Battery Energy Storage Systems, Arduino Uno microcontrollers, Raspberry Pi monitoring systems, relay modules, smoke sensors, GSM communication modules, alarm buzzers, and automated fish feeders. These components were integrated to create a hybrid renewable-energy microgrid and aquaculture support platform capable of autonomous operation.

Software development involved the use of Arduino IDE, Python programming language, Raspberry Pi OS, and embedded automation algorithms. The system was programmed to monitor energy production, battery conditions, smoke detection, feeding schedules, and environmental conditions in real time. GSM-based SMS notifications were implemented to provide immediate alerts during abnormal operating conditions.

Testing and calibration procedures were conducted to evaluate sensor accuracy, communication reliability, automated responses, and overall system functionality. The researchers also assessed the system's capability to support sustainable aquaculture operations and improve disaster preparedness within coastal environments.



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IV. RESULTS AND DISCUSSION

System Implementation

The Blue-Coast Resilience Hub was successfully implemented as an integrated renewable-energy and aquaculture support system. The hybrid microgrid effectively combined solar, wind, and hydro-generated power with battery storage to provide continuous electricity for aquaculture operations and monitoring devices. Testing showed stable power management and reliable energy distribution under simulated operating conditions.

The automated fish-feeding mechanism successfully operated according to programmed schedules using Arduino-based control systems and RTC modules. The system reduced manual intervention while ensuring consistent feeding operations for aquaculture management. Monitoring results also confirmed that the Raspberry Pi dashboard effectively displayed real-time operational data including battery status, energy production levels, and environmental conditions.

Safety monitoring mechanisms also demonstrated reliable performance during testing. The smoke sensor successfully detected hazardous conditions, while the GSM module transmitted SMS notifications to registered mobile devices. The buzzer alarm provided immediate local alerts to improve emergency response capability within the system.

Overall findings demonstrated that the proposed resilience hub improves energy reliability, aquaculture productivity, and disaster preparedness. The integration of renewable-energy technologies, automation systems, and GSM-based monitoring provides a sustainable and scalable framework capable of supporting coastal communities and improving long-term operational resilience.

Evaluation Results

Category	Mean	Interpretation
Functionality	4.60	Strongly Agree
Reliability	4.60	Strongly Agree
Accuracy	4.60	Strongly Agree
Efficiency	4.70	Strongly Agree
Overall Mean	4.63	Strongly Agree

The functionality of the integrated aquaculture and renewable-energy system was evaluated based on its overall operational performance, user interaction, and system integration, resulting in an overall mean score of 4.60, interpreted as Strongly Agree. Respondents affirmed that the system operates smoothly as a unified platform (4.64) and effectively supports essential aquaculture processes such as fish production, storage, and processing (4.64). The monitoring and control system was also rated highly (4.56), indicating that it is user-friendly for fisherfolk. Additionally, the system's ability to provide timely alerts and performance updates (4.56) further enhances its usability and responsiveness. The scalability of the hub (4.64) demonstrates its adaptability for future expansion or upgrades. Overall, the findings indicate that the system performs its intended functions efficiently and integrates its components seamlessly in real-world applications.

The reliability of the system was assessed in terms of operational stability, consistency, and maintainability, yielding an overall mean score of 4.60, interpreted as Strongly Agree. Respondents confirmed that the system remains operational even during extreme weather conditions (4.54), highlighting its resilience in challenging

environments. The aquaculture and energy subsystems were found to function dependably with minimal breakdowns (4.52), while the microgrid provides a consistent and uninterrupted power supply (4.62). Maintenance procedures were also rated positively (4.58), indicating their effectiveness in ensuring long-term system stability. Notably, the community management team received the highest rating (4.72), reflecting strong confidence in their ability to operate and maintain the hub reliably. These results demonstrate that the system is robust, dependable, and sustainable over time.



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The accuracy of the system was evaluated based on its ability to match energy demand, generate reliable forecasts, and deliver precise information, with an overall mean score of 4.60, interpreted as Strongly Agree. Respondents agreed that the renewable-energy microgrid accurately meets the energy demands of the aquaculture system (4.64 and 4.52) and effectively forecasts renewable energy generation from sources such as solar, wind, and tidal (4.64). The projected benefits of the system were also found to align with the actual improvements experienced by fisherfolk (4.58), indicating reliable performance outcomes. However, the SMS alert functionality received a slightly lower mean score (4.48), interpreted as Agree, suggesting minor limitations in message delivery or consistency. Despite this, the overall findings indicate that the system provides accurate data and dependable performance in supporting aquaculture operations.

The efficiency of the system was measured in terms of resource utilization, energy management, and recovery performance, achieving the highest overall mean score of 4.70, interpreted as Strongly Agree. Respondents strongly agreed that the microgrid efficiently distributes power across all facilities (4.72) and minimizes energy loss during storage and transmission (4.52). The system's ability to reduce operational costs compared to traditional energy sources received the highest individual rating (4.76), emphasizing its economic advantage. Furthermore, the aquaculture system was found to efficiently utilize water, feed, and energy resources (4.68), while also demonstrating quick recovery from power interruptions or technical issues (4.66). These results highlight the system's effectiveness in optimizing both energy and aquaculture operations, making it highly efficient for practical implementation.

The table illustrates the survey findings, showing that the BLUE-COAST Resilience Hub: A Community- Driven Aquaculture & Renewable-Energy Microgrid for Coastal Fisherfolk in Carcanmadcarlan obtained notably high ratings from respondents. The computed mean scores ranged from 4.48 to 4.76, which correspond to the interpretation of Agree to Strongly Agree. The highest evaluations were recorded in terms of community relevance, sustainability, and overall acceptability, indicating that respondents perceived the project as useful, appropriate, and beneficial to their needs. Comparatively lower yet still positive ratings were observed in areas such as system maintenance and long-term operational reliability, highlighting aspects that may require further improvement. Overall, the survey results confirm that the BLUE-COAST Resilience Hub is widely accepted, impactful, and aligned with community needs, making it a promising solution for enhancing coastal resilience and sustainable livelihoods.

V. CONCLUSION

The study successfully developed the Blue-Coast Resilience Hub as an integrated renewable-energy microgrid and automated aquaculture support system designed for coastal fisherfolk communities in CarCanMadCarLan. The system effectively addressed challenges related to unreliable electricity access, operational inefficiency, and disaster vulnerability through the integration of renewable-energy technologies, automation systems, and GSM-based monitoring mechanisms.

The findings confirmed that hybrid renewable-energy systems combined with automated aquaculture technologies improve energy reliability, operational sustainability, and coastal resilience. The developed prototype demonstrated reliable performance in terms of monitoring, communication, safety management, and automated operation.

The study also provides a practical framework for future researchers, local government units, and coastal organizations interested in implementing community-centered renewable-energy systems for disaster-resilient coastal development. Future improvements may focus on advanced monitoring systems, expanded renewable-energy capacity, and long-term deployment within larger coastal communities.



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