International Journal of Engineering, Science and Information Technology
Volume 6 No. 2 (2026) pp. 90-96
ISSN 2775-2674 (online)
Website: http://ijesty.org/index.php/ijesty
DOI: https://doi.org/10.52088/ijesty.v6i2.1840
Research Paper, Short Communication, Review, Technical Paper

Enhancing the Income of Mie Lidi Microenterprises in the Underdeveloped Village of Banjarsari, Demak Regency Through the Implementation of Solar-Powered Portable Automatic IoT Blower Technology

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The manuscript was received on 2 July 2025, revised on 1 Ocotober 2025, and accepted on 20 April 2026, date of publication 24 April 2026

Abstract

This study investigates the integration of solar energy technologies to improve operational efficiency, reduce production costs, and enhance income generation among micro and small enterprises in rural Indonesia. The research focuses on the mie lidi processing sector in Banjarsari Village, Demak Regency, where traditional drying practices remain highly dependent on weather conditions, resulting in inconsistent production quality and limited productivity. To address these challenges, the study introduces a solar-powered Portable Automatic Internet of Things (IoT) Blower designed to automate and optimize the drying process while utilizing renewable energy as the primary power source. The proposed system incorporates two 550-watt monocrystalline solar panels integrated with IoT-based monitoring and automated airflow control mechanisms. Performance evaluation demonstrates that the solar energy system generates an average of 6.69 kilowatt-hours (kWh) of electricity per day, equivalent to approximately 187.2 kWh per month. Meanwhile, the blower requires only 0.864 kWh of energy per day, representing 12.9% of total energy production, thereby creating a substantial energy surplus that supports long-term operational sustainability. The implementation of the system produces estimated monthly electricity cost savings of IDR 270,447.24, significantly reducing operational expenditures for local enterprises. Beyond economic benefits, the automated drying technology enhances production consistency by eliminating dependence on fluctuating weather conditions and reducing processing delays. The integration of renewable energy and smart automation also contributes to environmental sustainability through lower carbon emissions and reduced reliance on fossil-fuel-based electricity. The findings indicate that solar-integrated IoT drying systems offer a practical, scalable, and environmentally friendly solution for strengthening rural entrepreneurship, increasing productivity, and supporting sustainable economic development. Furthermore, the proposed model provides a replicable framework that can be adopted by other rural communities with similar climatic and socio-economic conditions to promote energy independence and resilient local industries.

Keywords: *Solar Energy, Rural Microenterprise, Energy Efficiency,Mie Lidi Production, IoT Integration.*

1. Introduction

Micro, Small, and Medium Enterprises (MSMEs) constitute the backbone of Indonesia's rural economy, particularly in underdeveloped regions where industrial infrastructure remains limited [1][2]. Among these, the mie lidi processing sector—characterized by the production of stick-like crunchy noodle snacks—has emerged as a promising source of income in Banjarsari Village, Demak Regency, Central Java. Despite its potential, this sector faces substantial operational challenges, particularly during the drying phase of production, which is traditionally conducted outdoors and is thus highly susceptible to climatic variability [3][4]. Rainy seasons reduce production capacity by up to 25%, adversely affecting product quality and the economic viability of the enterprises involved [5][6]. In light of these challenges, there is an urgent need for technological interventions that support both operational efficiency and environmental sustainability [7]. This study explores the deployment of a Portable Automatic IoT Blower system powered by solar photovoltaic (PV) panels as a practical and innovative solution to these limitations [8][9]. By decoupling the drying process from weather dependence and using renewable energy sources, this technology is expected to significantly increase production capacity, reduce energy costs, and enhance resilience among local MSMEs. Banjarsari Village is categorized as an underdeveloped area in Indonesia, with over 74% of its population living below the poverty

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line. The majority of residents rely on subsistence agriculture and small-scale home industries. In recent years, I have turned to an alternative livelihood, using affordable raw materials such as wheat flour to produce marketable snack products [10][11]. However, one key bottleneck to scaling up this enterprise is its reliance on sunlight for noodle drying, which creates inconsistent production schedules and makes the operation vulnerable to spoilage. The proposed intervention uses solar photovoltaic technology, combined with automated blower systems connected via IoT sensors, to control humidity, drying duration, and airflow. The selected system comprises two 550-watt monocrystalline solar panels, paired with a 12V 200Ah battery for energy storage, enabling operation even in low-light conditions. The IoT-enabled automation ensures consistent drying parameters, improving product quality while reducing human labor. From an economic standpoint, the transition from conventional manual drying to this semi-automated, energy-efficient model represents a strategic investment in both operational reliability and long-term cost reduction.

The overarching aim of this research is to assess the feasibility and impact of solar-powered drying automation on mie lidi production within the context of rural MSMEs. Specific objectives include:

a. **To enhance production capacity** by minimizing the dependency on external climatic conditions through the use of controlled, solar-powered drying systems.
b. **To reduce operational energy costs** by utilizing renewable solar energy as the primary power source, thereby lowering reliance on grid electricity or fuel-based alternatives.
c. **To improve product quality and consistency** by integrating automated controls that standardize the drying process, minimizing human error and spoilage.
d. **To promote sustainable business models** for rural MSMEs that align with national and global development agendas, particularly the United Nations Sustainable Development Goals (SDG 7 – Affordable and Clean Energy).

Through achieving these goals, the study seeks to contribute not only to the technical advancement of rural enterprise operations but also to the broader discourse on inclusive, sustainable economic development in underprivileged communities.

2. Literature Review

Micro, Small, and Medium Enterprises (MSMEs) serve as a critical component of Indonesia's economic fabric, particularly in underdeveloped rural areas. These enterprises contribute significantly to employment creation, income generation, and poverty alleviation. However, MSMEs in disadvantaged regions often face systemic challenges, including limited access to modern technology, constrained financing options, and a high dependence on external factors, such as weather, which directly influence production processes [12]. In Banjarsari Village, one of the most underdeveloped areas in Demak Regency, the mie lidi industry exemplifies these challenges, particularly because it relies on sunlight for drying. This dependency results in significant fluctuations in production output, which, in turn, affects the stability of income and the scalability of these enterprises. Argue that enhancing the productivity and efficiency of MSMEs in rural and remote areas requires the introduction of appropriate, sustainable technologies tailored to local resource availability [13]. In this context, renewable energy technologies—such as solar photovoltaic (PV) systems—offer viable alternatives to conventional energy sources. These technologies have the potential to ensure continuous operation in regions with unstable electricity supply while simultaneously promoting long-term environmental sustainability. The emergence of the Internet of Things (IoT) has introduced new paradigms for operational efficiency through interconnected, real-time automation. IoT technologies facilitate autonomous system control, data acquisition, and decision-making, thereby reducing human error and enhancing production consistency. Within the MSME context, IoT has proven effective in minimizing reliance on manual labor and optimizing production systems across sectors such as agriculture and food processing [14]. In the case of mie lidi production, the application of IoT-enabled systems—such as the Portable Automatic IoT Blower—allows for integrated temperature and humidity control, enabling precise, automated drying independent of climatic conditions. This real-time monitoring capability empowers rural entrepreneurs to manage operations remotely, ultimately improving productivity and resource utilization [15]. The utilization of solar energy as a renewable energy source has gained increasing attention in both academic discourse and practical implementation, particularly within the MSME sector [16][17]. Solar energy is abundant in tropical countries like Indonesia, making it an ideal candidate for rural applications. It can power a range of industrial devices, including automated blowers, while also enabling energy storage for off-grid usage during low-sunlight conditions [18][19]. Within MSME operations, solar panel installations offer dual benefits: reducing operational energy costs and enhancing sustainability by reducing dependence on fossil fuels. For example, a solar energy system employing 550-watt monocrystalline panels in combination with a 12V 200Ah LiFePO4 battery has been shown to support blower operation for up to six hours daily, with additional energy reserves for cloudy conditions. As demonstrated such systems can lead to substantial reductions in electricity costs while also improving energy efficiency and enterprise competitiveness. Beyond operational improvements, the social and economic implications of solar-powered technology adoption are profound. According renewable energy technologies can catalyze job creation and foster the development of new service sectors in regions traditionally characterized by limited economic diversification. In Banjarsari, the integration of solar-powered, portable, automatic IoT Blower systems is anticipated not only to enhance mie lidi production and income levels but also to reduce labor-intensive processes, elevate product quality, and introduce remote monitoring features that improve management efficiency. This comprehensive transformation aligns with the United Nations Sustainable Development Goals, particularly Goal 7: Affordable and Clean Energy, which emphasizes the deployment of renewable energy technologies to support sustainable and inclusive economic development. In sum, the literature underlines the strategic value of integrating solar photovoltaic systems and IoT technologies within rural MSME ecosystems. Such interventions not only address fundamental production bottlenecks but also provide a pathway toward resilient, scalable, and environmentally responsible enterprise models.

3. Methods

This research was conducted in Banjarsari Village, located in Sayung Sub-district, Demak Regency, Central Java, Indonesia. Banjarsari was selected as the study site due to its classification as an underdeveloped rural area with significant untapped potential for the

development of micro and small enterprises, particularly in the mie lidi processing sector. The research period commenced in March 2025 and is scheduled to be completed by August 2025.

The primary objective of this study is to implement a solar-powered Portable Automatic Internet of Things (IoT) Blower system within the production operations of local MSMEs to enhance production capacity and improve operational efficiency. The intervention focuses on replacing the conventional sun-drying method, which is highly dependent on unpredictable weather conditions, with an automated, climate-independent drying solution powered by renewable energy.

Fig 1. Mie Lidi Microenterprise in Banjarsari Village, Demak City

3.1. Tools, Materials, and System Design

This research employed a range of tools and materials, in accordance with predefined technical specifications, to implement a solar-powered mie lidi drying system. The equipment and components were selected to optimize energy efficiency, enable automation, and ensure consistent operation regardless of weather conditions.

Tools

a. Solar Panels: Two units of 550-watt monocrystalline photovoltaic (PV) panels were utilized due to their high efficiency in solar energy conversion and durability in varying environmental conditions.
b. Inverter: A 1 kW / 24V inverter was used to convert the direct current (DC) produced by the solar panels into alternating current (AC) suitable for operating industrial equipment.
c. Battery Storage: A 12V 200Ah lithium iron phosphate ($LiFePO_4$) battery served as the primary energy storage unit, ensuring uninterrupted operation during low-light conditions, such as nighttime or overcast weather.
d. Blower Unit: A 2 kW, 220V AC heater blower was employed to accelerate the mie lidi drying process by delivering hot airflow into the drying chamber.
e. Temperature Sensor: A digital temperature sensor was installed to measure and monitor the drying chamber temperature with high accuracy.
f. Control System: An RS-485-based control system was implemented to automatically regulate temperature and humidity levels in the drying space based on preset parameters.
g. Installation Accessories: H1Z2Z2-K 6mm solar cables and aluminum mounting rails were used to attach the solar panels to the rooftop installation area securely.

Materials

a. Photovoltaic Modules and Structural Frame: To support and stabilize the solar panels under varying environmental loads.
b. Aluminum Mounting System: Used for safe and adjustable installation of the PV modules on inclined roofs.
c. Electrical Connectors: MC4 connectors were applied to ensure weatherproof, safe, and efficient electrical connections between solar modules and system components.

System Design

The system was designed to integrate the Portable Automatic IoT Blower with solar photovoltaic technology to optimize mie lidi drying processes. Several key considerations guided the design phase:

a. Energy Demand Assessment: The system was sized to meet the energy requirements of the 2 kW blower, which typically operates for up to six hours per day.
b. Energy Storage for Off-Grid Operation: The $LiFePO_4$ battery bank was sized to store sufficient energy to maintain blower operation during periods of insufficient sunlight.
c. Automated Environmental Control: The RS485-based control unit was programmed to automatically maintain optimal temperature and humidity levels in the drying chamber, enhancing product consistency and quality.

3.2. Component Architecture Overview

a. PV1 and PV2 (550 WP): Two monocrystalline solar panels, each with a capacity of 550 watts.
b. Grid Connection (PLN): The system includes a fallback connection to the national electricity grid to ensure continuous operation if solar energy is insufficient.

a. Inverter SNV-GF1021 (1 kW / 24V): Converts DC electricity from solar panels into AC power suitable for standard equipment.
b. Battery Input and Auxiliary AC Input: Allows dual input energy storage from both solar and grid-based sources.
c. AC Output: Supplies stable alternating current to power the load—in this case, the IoT blower unit.

This integrated system design aims to ensure operational autonomy, energy reliability, and cost efficiency for mie lidi producers in Banjarsari Village. It represents a scalable model for other rural MSMEs facing similar production constraints due to climate dependence and limited energy access.

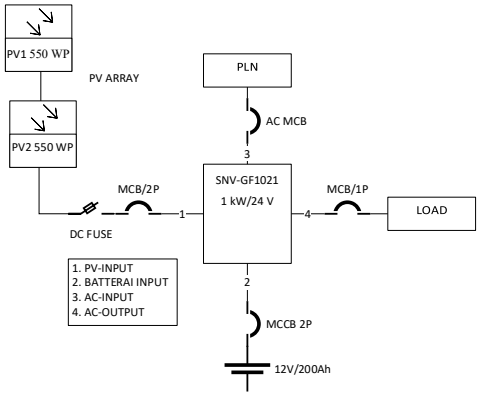

Fig 2. Hybrid Solar Panel System with 1 kW/24V Inverter

3.3. Implementation Stages

The implementation of the Portable Automatic IoT Blower integrated with solar panels was carried out through several structured stages to ensure the program's success and smooth execution. These stages began with initial socialization efforts and continued through post-implementation monitoring to verify optimal system functionality. Each phase was carefully designed to involve all relevant stakeholders-including MSMEs, technicians, and village authorities—to foster sustainability and ensure broad community acceptance of the technology. The stages of implementation included:

a. Socialization: Community outreach sessions to introduce MSME participants to the benefits and usage of the technology.
b. Training: Technical and operational training on equipment usage, maintenance procedures, and technology-based business management.
c. Technology Deployment: Installation of the system components and initial field testing.
d. Assistance and Evaluation: Ongoing technical support for three months, accompanied by regular system performance evaluations.
e. Program Sustainability: Establishment of independently managed business groups and enhancement of mie lidi product marketing networks.

Each of these stages emphasizes inclusive participation and collaboration, aiming to ensure effective technology adoption, provide tangible benefits to MSMEs, and contribute to the sustainable economic development of the village.

4. Result and Discussion

The solar energy potential in Banjarsari Village was assessed based on the solar radiation intensity received by the installed photovoltaic (PV) panels in the area. Radiation data used in the estimation were obtained through both on-site measurements and publicly available information from the national meteorological agency. According to the Meteorology, Climatology, and Geophysics Agency [20]Banjarsari Village receives approximately 420 W/m² of solar irradiance, with an average of 5 peak sun hours per day.

Solar irradiance measurements were conducted using a solar radiation meter (solar meter), which records the amount of solar energy received per unit surface area, expressed in Watts per square meter (W/m²). These measurements were taken periodically over several months to obtain a more accurate estimate of the region's solar energy potential.

Based on these findings, the estimated solar energy potential was calculated using two 550-WP monocrystalline solar panels installed at the research site. To determine the daily solar energy yield, several key variables were considered, including:

1. Solar radiation intensity (W/m²),
2. Surface area of each solar panel (m²),
3. Average solar exposure time (hours/day),
4. Number of installed panels.

Each 550 WP panel has an approximate surface area of 1.5 m², and the site receives about 5 effective sun hours per day. The following equation was applied to estimate the potential solar energy output:

4.1. Estimated Daily Energy Output (Wh/day)

= Panel Power (Wp) × Number of Panels × Peak Sun Hours
= 550 W × 2 panels × 5 hours
= 5,500 Wh/day or 5.5 kWh/day

This calculation provides a foundational understanding of the energy production capacity of the solar panel system deployed in Banjarsari Village, which is then used to support the operation of the Portable Automatic IoT Blower in the targeted MSMEs.

Table 1. Weekly Energy Output Estimation from Two Solar Panels

Day	Estimated Solar Radiation (W/m²)	Sunlight Duration (hours)	Solar Energy Output (Wh)
Monday	420	5	6,300
Tuesday	400	5	6,000
Wednesday	450	5	6,750
Thursday	470	5	7,050
Friday	430	5	6,450
Saturday	460	5	6,900
Sunday	490	5	7,350

Daily Solar Radiation and Energy Output from Dual Solar Panel Systems in Supporting Energy Efficiency for Rural Micro-enterprises in Banjarsari Village, Demak City.

The amount of solar radiation received daily directly influences the energy output of solar panel systems. In this study, energy production from two solar panel units installed in Banjarsari Village, Demak Regency, was monitored over 1 week to evaluate their performance and potential to support local micro-enterprise operations, particularly for drying stick noodles.

a. Monday: On the first day, energy production reached 6,300 Wh, based on a solar radiation intensity of 420 watts per square meter over 5 hours of solar exposure.
b. Tuesday: Solar radiation was recorded at 400 watts per square meter, generating 6,000 Wh.
c. Wednesday: With a radiation level of 450 watts per square meter, energy production increased to 6,750 Wh.
d. Thursday: The radiation peaked at 470 watts per square meter, resulting in an output of 7,050 Wh.
e. Friday: A slight drop in solar radiation to 430 watts per square meter produced 6,450 Wh.
f. Saturday: Energy production reached 6,900 Wh with solar radiation at 460 watts per square meter.
g. Sunday: The highest radiation level of the week, 490 watts per square meter, yielded the maximum energy production at 7,350 Wh.

Daily energy output ranged from 6,000 Wh to 7,350 Wh, depending on solar radiation variability. The average daily energy production was approximately 6.69 kilowatt-hours (kWh), derived from two solar panels with a capacity of 550 watts-peak and an average daily solar exposure of 5 hours.

This analysis provides critical insights into the daily solar energy potential available for operational needs in the rural micro-enterprise sector. For instance, this energy can be utilized to power the drying systems for stick noodle production, thereby reducing reliance on conventional fossil fuels.

4.2. Weekly and Monthly Solar Energy Estimations

To determine the weekly energy potential, the average daily production of 6.69 kWh was multiplied by 7 days, resulting in a total of 46.8 kWh per week. This figure shows daily fluctuations in solar radiation while confirming the reliability of solar power as an energy source. Every month, multiplying the weekly energy output by 4 yields an estimated monthly energy output of 187.2 kWh. This monthly energy potential is sufficient to support the continuous operation of solar-powered equipment, such as the stick noodle dryer, even under suboptimal weather conditions.

4.3. Summary of Solar Energy Potential in Banjarsari Village

a. Average Daily Solar Energy Production: 6.69 kWh
b. Average Weekly Solar Energy Production: 46.8 kWh
c. Average Monthly Solar Energy Production: 187.2 kWh

Despite daily fluctuations, the system consistently provides sufficient energy to meet the operational demands of rural microenterprises. The inclusion of a battery storage system further enhances the reliability of energy availability during night hours or periods of low solar radiation.

4.4. System Efficiency Evaluation: Solar Energy and Portable Automatic IoT Blower

To assess the efficiency of the solar energy system, it is essential to compare the energy generated with the energy consumed by the equipment it powers—specifically, the Portable Automatic Internet-of-Things (IoT) Blower used for noodle drying.

a. Energy Consumption by the Blower
b. The blower operates at 144 watts for 6 hours per day. Therefore, daily energy consumption is calculated as: 144 W × 6 hours = 864 Wh (or 0.864 kWh)
c. Energy Generation by the Solar Panel System
d. The previously established daily energy production of the solar panel system is 6.69 kWh.
e. Efficiency Comparison
f. The ratio between energy consumed and energy produced provides insight into system efficiency. The blower consumes 0.864 kWh, which is approximately 12.9% of the 6.69 kWh generated. This indicates that the system produces substantially more energy than is required for the blower's operation, allowing the surplus energy to be stored or allocated to other devices.

4.5. Economic Impact: Cost Savings from Solar Energy Integration

Assuming an electricity tariff of IDR 1,444.70 per kWh, the cost savings derived from solar energy utilization can be estimated. The monthly savings from powering the blower exclusively with solar energy are: 0.864 kWh/day × 30 days × IDR 1,444.70 = IDR 37,380.48. However, considering the total energy generated (187.2 kWh), the broader potential monthly savings reach: 187.2 kWh × IDR 1,444.70 = IDR 270,447.24. This substantial reduction in electricity costs enhances the long-term sustainability and economic viability of rural micro-enterprises.

5. Conclusion

Based on the calculations and analysis conducted, it can be concluded that the implementation of a solar energy system comprising two 550-watt peak monocrystalline solar panels in Banjarsari Village has proven both efficient and sustainable in supporting micro-enterprise operations, particularly in the stick noodle drying process. The following conclusions are derived from the performance evaluation:

a. The average daily energy production from the two solar panel units is approximately **6.69 kilowatt-hours**. Despite daily variations in solar radiation, this amount of energy is sufficient to meet the operational requirements of the blower, a core component of the drying system at the local micro-enterprise. Every week, the solar panel system produces **46.8 kilowatt-hours**, demonstrating a consistent energy output capable of supporting uninterrupted operations. Assuming a four-week month, the system generates **187.2 kilowatt-hours, providing a reliable,** sustainable energy supply that reduces dependence on conventional electricity sources and lowers operational costs.
b. Efficiency calculations indicate that only **12.9 percent** of the total generated energy is required to operate the blower. The surplus energy can be stored in batteries and used during non-solar hours, such as at night or on overcast days. This allows the system to operate autonomously without reliance on external energy sources. Furthermore, implementing this solar energy system results in substantial financial savings for micro-enterprises in Banjarsari Village, amounting to approximately **IDR 270,447.24 per month**. This underscores the dual benefit of renewable energy systems: enhancing operational efficiency and achieving financial sustainability by reducing conventional electricity costs.
c. The solar energy system presented in this study has proven to be an effective solution for meeting the energy demands of rural micro-enterprises, while simultaneously offering long-term benefits in reducing fossil fuel dependency. The significant energy output and operational cost savings highlight the potential of this technology to contribute to sustainable, environmentally friendly rural development.

Future recommendations include:

a. Scaling the implementation of similar systems in other rural villages with comparable solar energy potential.
b. Enhancing the system's energy storage capacity further to improve autonomy during periods of low solar irradiance.
c. Integrating advanced monitoring technologies, such as Internet-of-Things-based sensors, to optimize energy management, track real-time performance, and improve maintenance efficiency.

This approach aligns with national strategies for rural electrification, digital transformation, and green energy innovation, and offers a replicable model for empowering micro-enterprises in underdeveloped areas across Indonesia.

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