ENERGY PROFILING AND EFFICIENCY ENHANCEMENT OF SELECTED MICRO-SMALL-MEDIUM ENTERPRISES IN ILOCOS NORTE, PHILIPPINES

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APPROVAL SHEET

This capstone project titled, **ENERGY PROFILING AND EFFICIENCY ENHANCEMENT OF SELECTED MICRO-SMALL-MEDIUM ENTERPRISES IN ILOCOS NORTE, PHILIPPINES**, prepared and submitted by **JOMEL C. FELIX**, in partial fulfillment of the requirements for the degree, Professional Science Masters in Renewable Energy Engineering, is hereby accepted.

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ABSTRACT

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Businesses are under more pressure to improve operational efficiency as energy costs rise and demand for sustainability grows. Navigating limited resources while striving for more efficient energy use presents a challenge for micro, small, and medium-sized enterprises (MSMEs) in maintaining their competitiveness and resilience. This study investigated the daily operational energy consumption patterns of MSMEs in Ilocos Norte. It also assessed the energy awareness of corporate operators within these businesses. Based on these insights, the research proposed doable plans aimed at cutting energy use and improving energy efficiency for the MSMEs in the region.

Using a mixed-methods approach, the study collected equipment-level energy data and conducted pre- and post-awareness surveys. The study gathered operational practices recorded inside businesses as well as directly from energy consumption data. Either through guided conversations in person or through independent reading in digital formats, participants engaged with an educational brochure outlining basic energy-saving techniques. To determine the efficacy of the intervention, awareness levels were measured both before and after material exposure.

Results show that refrigeration, lighting, and cooling were the most energy-intensive categories. Microenterprises, which comprised 87.6% of respondents, mostly fell under the lowest energy intensity band (<20 kWh). Following the awareness

intervention, the mean awareness score significantly increased by 21.3%—from 19.71 to 23.91 ($p < 0.001$). Participants showed more awareness of energy management and more openness to applying energy-saving techniques after the intervention. A total of 118 MSMEs expressed interest in solar PV system recommendations. Customized solar PV system recommendations ranged from 1 kWp to 96 kWp, with 61.02% of respondents suited for 1 kWp setups. Projected monthly energy savings ranged from PHP 1,426.70 to PHP 136,963.53, depending on system size. A total of 94.57% of MSMEs indicated interest in renewable energy adoption.

By not only identifying areas in need of improvement but also arming MSMEs with the required knowledge to adopt sustainable practices inside their operations, the study successfully addressed its main objectives. The study demonstrates that with the right knowledge and tools, MSMEs can significantly reduce operational costs and enhance sustainability. Findings support the formulation of localized energy interventions and policies that empower MSMEs to contribute to broader renewable energy and climate goals.

CHAPTER I

INTRODUCTION

Background of the Study

Political economy concerns and market failures present serious obstacles to the Philippines' energy consumption and efficiency (Yap et al., 2020). Despite having a comparatively high proportion of renewable energy in its generation mix, the nation lags behind its Asian neighbors in terms of energy access. Indeed, energy consumption is influenced by various factors, including GDP, industrialization, urbanization, and financial development (Sabado et al., 2022). Weather variability also plays a role, particularly affecting electricity consumption in rural, female-headed households (Bayudan-Dacuycuy, 2017). Furthermore, as the Philippine economy progresses, residential energy consumption is expected to increase with improved living conditions (Enteria & Cuartero, 2017). To address these challenges, the Department of Energy has implemented programs and policies, but their effectiveness is hindered by political factors (Yap et al., 2020).

Interestingly, energy conservation policies may not substantially hurt the economy, despite the fact that energy consumption and carbon emissions are positively correlated. Conversely, energy consumption and economic growth are negatively correlated (Deang et al., 2022). The largest portion of electricity consumption in educational buildings comes from air conditioning (51%), followed by equipment use (35%) and lighting (14%). (Lopez et al. 2017). Therefore, to tackle these issues, policymakers ought to think about augmenting the proportion of renewable energy sources, executing technologies that mitigate pollution, and embracing energy-conserving measures like enhanced lighting and air conditioning systems (Deang et al., 2022; Lopez et al., 2017).

In 2020, the Philippines' total primary energy supply was 2,384,351 terajoules (TJ), of which 66.5% came from non-renewable sources and 33.5% from renewable sources (International Renewable Energy Agency [IRENA], 2023a). By 2022, the country consumed 546 terawatt-hours (TWh) of electricity, of which more than 4.77 TWh came from fossil fuels like coal and gas (Ritchie et al., 2020). The Philippines has set targets to increase the renewable energy share to 35% by 2030 and 50% by 2050, highlighting the importance of energy efficiency in achieving these goals (International Trade Administration, 2024)

Micro, small, and medium-sized enterprises (MSMEs) comprise 99.6% of all businesses in the Philippines and are vital to the country's economic development (Ibarra & Velasco, 2015). Specifically, these businesses are crucial for generating wealth, innovation, and jobs, especially in rural areas (Nwosu & Umeh, 2021). The Philippines' competitive advantage in ASEAN integration and the global market is largely attributed to MSMEs (Nwosu & Umeh, 2021). However, although the majority of MSMEs show an understanding of accounting concepts and procedures, there are some discernible variations between those in Quezon Province and Metro Manila (Ibarra & Velasco, 2015). In the global knowledge-based economy, MSMEs confront a number of difficulties despite their significance (Roldan, 2015). Consequently, an environment of supportive policies is required to achieve sustainable growth (Roldan, 2015). To increase the potential of the Philippine MSME sector for development and sustainability in the global economy, European linking mechanisms and assistance are being investigated (Roldan, 2015).

Statement of the Problem

The energy consumption challenges faced by MSMEs in Ilocos Norte, Philippines, are severe and negatively affect their competitiveness, sustainability, and operating costs. Excessive energy costs and wasteful energy use are prevalent issues that require a careful analysis of energy usage trends and the pinpointing of possible areas for improvement.

In order to better understand and optimize energy consumption in particular MSMEs, energy profiling is conducted as part of this effort, along with identifying opportunities for energy optimization by evaluating and documenting the patterns in current energy consumption. Formulating specific recommendations to enhance energy management techniques is another important goal.

Generally, this study sought to enhance energy management in MSMEs by addressing issues with best practices, common consumption patterns, adoption barriers, and efficient approaches.

Specifically, this study aimed to answer the following research questions:

1. What is the present energy usage of Ilocos Norte's MSME sector?
2. What are the present energy usage patterns of Ilocos Norte's MSME sector?

3. What approaches can help MSMEs become more conscious of and adopt energy-efficient practices?
4. What are the energy efficiency opportunities and potential areas for improvement within these MSMEs?
5. Which best practices can MSMEs use to increase their competitiveness and sustainability?

Objectives of the Study

This study generally aimed to conduct energy profiling in order to understand and optimize energy consumption in Philippine micro, small, and medium enterprises (MSMEs). Specifically, the study aimed to:

1. determine the current electricity consumption of selected MSMEs in Ilocos Norte by collecting equipment-level energy estimates;
2. analyze daily and monthly energy usage patterns, identifying energy intensive processes;
3. assess MSME awareness and adoption of energy-efficiency practices;
4. identify opportunities to improve energy efficiency based on energy efficiency enhancement practices applicable to the MSMEs; and
5. recommend solar PV setup as an energy-efficient alternative best practice to increase their competitiveness and sustainability.

Significance of the Study

This study could provide each participant with actionable practices, even though it may use various data collection techniques and concentrate on a representative sample. Ultimately, this project could empower them by increasing their knowledge of energy-saving techniques, enabling them to make decisions that could save costs, improve sustainability, and boost their competitiveness.

This study is important because it tackles critical issues regarding energy usage that directly affect the operating costs, sustainability, and competitiveness of MSMEs in Ilocos Norte, Philippines. Specifically, by conducting an energy profile and examining current usage patterns, the study could find inefficiencies and opportunities for optimization. Consequently, this could result in lower operating expenses, significantly improving MSMEs' competitiveness and financial stability.

Moreover, encouraging energy-saving practices could lower carbon emissions, which directly supports environmental sustainability. Beyond that, the study also could provide MSMEs with the information and resources they need to adopt efficient energy management techniques by raising awareness and developing their capabilities. Policymakers and stakeholders, for their part, could benefit from the study's insights, which may lead to more supportive programs and policies. Ultimately, creating a more cost-effective and sustainable operating environment would facilitate the long-term survival and expansion of MSMEs in Ilocos Norte, thus benefiting the local business community as well as the region's economy, environment, and society at large.

Scope and Limitations of the Study

The aim of this study is to help MSMEs in Ilocos Norte, Philippines, optimize their energy consumption. A representative sample based on purposive sampling for MSMEs was invited to participate in the survey.

However, one limitation is that the study may not fully represent the entire population of MSMEs in Ilocos Norte. Nonetheless, participants in this research comprise a heterogeneous group of respondents from the MSME sector in Ilocos Norte, Philippines. This includes company owners and managers who oversee both the day-to-day operations and long-term planning of their businesses. This extensive sample of respondents, therefore, guarantees a comprehensive grasp of the trends in energy consumption, as well as the obstacles and prospects facing MSMEs in the region. Another limitation of this study is that the recommended energy efficiency alternatives are only provided as a single-line diagram exported from simulator software or as recommendations based on manual computations of daily usage. Consequently, the decision to adopt and implement these recommendations is rest entirely with the individual MSMEs.

Furthermore, the recommendations provided for solar PV systems are based exclusively on the estimated daily energy consumption of electrical equipment and the corresponding requirements for battery storage. Crucially, the discussion does not encompass technical elements such as inverter sizing, charge controller selection, cable and wire sizing, circuit breakers, mounting structures, grounding systems, or other materials required for a comprehensive system installation. The objective of this simplified calculation is, instead, to equip MSMEs with a basic comprehension of their energy needs and potential solar battery configurations.

Finally, the recommendations in this paper focus solely on solar photovoltaic (PV) systems as the main alternative renewable energy source. Other renewable energy technologies, including hydro, biomass, and wind, were excluded based on factors of feasibility, availability, and relevance to the operational setting of the chosen MSMEs.

CHAPTER II

REVIEW OF LITERATURE

This section delineates the resources and documentation investigated by the researcher to build an adequate base for the study. The evaluated literature encompasses the following: 1) Overview of Micro, Small, and Medium-sized Enterprises in the Philippines; 2) Energy Use and Efficiency Concerns in MSMEs; 3) Government Programs and Policy Frameworks on Energy Efficiency and Conservation; 4) Guidelines and Best Practices for Micro, Small, and Medium-sized Enterprises; 5) Case Examples of RE Integration in Philippine MSMEs; 6) Basic Energy Efficiency Measures and Technologies.

Overview of Micro, Small, and Medium-sized Enterprises in the Philippines

MSMEs play a significant role in the Philippine economy because of their impact on employment, income, and overall economic development. The Philippines uses asset size and employment as its two operational definition criteria for MSMEs. An organization is categorized as a microenterprise by the Philippine Statistics Authority if it employs fewer than ten people, as a small enterprise if it employs ten to ninety-nine people, as a medium enterprise if it employs one hundred to ninety-nine people, and as a large enterprise if it employs two hundred or more people. The Small and Medium Enterprise Development Council (SMEDC), on the other hand, bases its classification system on asset size, as shown in Table 1 (Philippine Statistics Authority [PSA], 2022).

Table 1. Criteria for categorizing Philippine MSMEs (PSA, 2022).

Size	By Employment	By Asset Size
Micro	1-9 employees	Up to Php 3,000,000.00
Small	10-99 employees	Php 3,000,001.00-Php 15,000,000.00
Medium	100-199 employees	Php 15,000,001.00-Php 100,000,000.00

As per the 2022 List of Establishments (LE) released by the Philippine Statistics Authority (PSA), there were 1,109,684 registered businesses in the Philippines. MSMEs make up 1,105,143 (99.59%) of these, while major firms make up 4,541 (0.41%). Microfirms comprise 0.40% (4,484) of the remaining 8.69% (96,464) of all establishments, while small businesses make up 90.49% (1,004,195) of all establishments (Department of Trade and Industry, 2023). Currently, there are 22,490 registered MSMEs in Ilocos Norte as of January 2024. It has 21,735 micro, 517 small, and 178 medium-sized enterprises (See Appendix C).

Energy Use and Efficiency Concerns in MSMEs

MSMEs face persistent challenges in managing energy consumption due to inefficiencies in operations, high utility costs, and limited access to clean energy technologies. According to Yap et al. (2020), energy-related problems in the Philippines are deeply rooted in political economy issues and market failures, leading to poor energy access, especially in rural areas where most MSMEs operate. Despite the country's high share of renewable energy in its generation mix, actual access and affordability remain low for small businesses due to infrastructure gaps, limited incentives, and bureaucratic constraints.

Energy demand among MSMEs is driven by business type, equipment use, and operational hours. Sabado et al. (2022) found that factors like GDP growth, urbanization, and financial development significantly influence energy consumption, highlighting that as MSMEs grow, their energy needs also rise. However, these enterprises often operate with outdated equipment and without proper energy management systems, leading to wastage and inflated operating costs. In educational and commercial settings, Lopez et al. (2017) noted that air conditioning consumes as much as 51% of total electricity, followed by office and lighting equipment, which reflects typical MSME energy profiles.

Furthermore, Deang et al. (2022) emphasized that although energy consumption and carbon emissions are generally positively correlated, efficient energy policies can reduce consumption without harming economic growth. Yet, many MSMEs lack awareness and capital to adopt such policies or invest in cleaner technologies.

Government Programs and Policy Frameworks on Energy Efficiency and Conservation

The Philippines has implemented various government programs and policy framework to promote energy efficiency, sustainability and green economic development, particularly among MSMEs.

Promotion of Green Economic Development. A noteworthy program called the Promotion of Green Economic Development (ProGED) aims to improve the competitiveness and sustainability of MSMEs. The Department of Trade and Industry (DTI) launched this initiative, which focuses on putting into practice inclusive, climate-sensitive, and environment-friendly strategies—particularly in the tourism sector, which is essential for the nation's economic growth and job creation. Later on, the initiative spread to other parts of the Philippines, starting in the provinces of Cebu and Bohol (*Promotion of Green Economic Development (Pro GED) | Migration for Development*, n.d.).

The main goal of ProGED is to increase MSMEs' awareness of the need to implement green strategies in order to reduce their risk of climate change. The process entails arranging training sessions on "Green Business Literacy" to enlighten MSMEs on how to allocate their remittances towards sustainable business practices. These practices include solid waste management, energy efficiency, and the utilization of environment-friendly materials that are sourced locally (*Promotion of Green Economic Development (Pro GED) | Migration for Development*, n.d.). The creation of a Green Growth Core Group, which encourages industry associations to incorporate greening measures into their operational roadmaps and advocates for green economic development at the policy level, is one of the initiative's major achievements (Department of Trade and Industry [DTI], 2020).

ProGED accomplished a number of noteworthy things as of 2016. It organized 308 greening sensitization and learning events that attracted 13,683 MSMEs and stakeholders. It supported 260 MSMEs in their nomination for green awards, of which 84 were publicly acknowledged. It also organized 69 events that brought together green service providers and technology suppliers, involving 2,147 MSMEs. And it helped 37 MSMEs go green (DTI, 2020).

Additionally, the program has helped MSMEs and green service providers match, which has promoted cooperation and knowledge sharing (Greenconvergence, n.d.). ProGED seeks to build a more resilient and environmentally sustainable private sector by utilizing the investments and skills of the Filipino diaspora living abroad. (*Promotion of Green Economic Development (Pro GED) | Migration for Development*, n.d.)

Energy Efficiency and Conservation Roadmap (2023-2050). The Department of Energy (DOE) has identified MSMEs as one of the industry sectors to be targeted in its medium-term (2026–2030) Energy Efficiency and Conservation Roadmap 2023–2050. Its entire strategic approach consists of scoping and creating sector-specific initiatives for energy-intensive businesses, with an emphasis on MSMEs. There may be a large potential for energy savings from these programs that target energy-intensive industries. The 2017–2040 Roadmap included sector-focused projects, and it was suggested that high-energy-consumption industries like sugar and cement be the focus of these initiatives. Since then, studies have indicated that the significance of these industries may not have been as great as first thought, and more research is needed to determine the target sectors. MSMEs should be another area of attention for these programs in order to encourage the adoption of energy efficiency in this subsector. This would be in line with development goals and connect to the DOE's goal of more inclusive energy efficiency initiatives across industries like the manufacturing sector. Prospective directions for investigation encompass creating and testing energy-saving initiatives in cold-chain sectors, initiatives aimed at promoting the use of a certain technology through advantageous funding, and so forth (DOE, Philippines, n.d.).

Their intended action is to conduct a market survey to gather baseline data on

MSMEs. Create a database for MSMEs with information on projects completed, annual energy consumption, registry lists, etc. Create initiatives that support energy efficiency, such as energy management, energy audits, conservation and energy-saving techniques, and project finance (Department of Energy, Philippines, n.d.).

Energy Efficiency and Conservation Act (EE&C Act) of the Philippines. The Philippines' Energy Efficiency and Conservation Act (EE&C Act), officially known as Republic Act No. 11285, has a number of important provisions designed to institutionalize energy conservation and efficiency as a way of life on a national scale. Here are the main provisions:

Scope. A framework for introducing and institutionalizing fundamental policies on energy conservation and efficiency is established by the Act. These policies include encouraging the wise and efficient use of energy, increasing the use of energy-efficient and renewable energy technologies, and outlining the roles and responsibilities of different government agencies and private organizations (*Republic Act No. 11285*, n.d.) (Admin, 2022).

Roles and Responsibilities. The DTI's Bureau of Philippine Standards (DTI-BPS) is consulted when developing, enforcing, and reviewing the Minimum Energy Performance (MEP). They mandate that producers, importers, and dealers adhere to the MEP and put the energy label on their goods (Admin, 2022) (*Energy Efficiency and Conservation Act (Republic Act No. 11285 of 2018) | ESCAP Policy Documents Management*, n.d.). Building and utility system energy-conserving design guidelines are implemented by the Department of Public Works and Highways (DPWH) (Admin, 2022).

Manufacturers, importers, and dealers must adhere to the MEP and show the energy label on products, per the Department of Trade and Industry (DTI) regulations (Admin, 2022). All energy end users must utilize available energy resources efficiently and encourage the development and application of new and alternative energy-efficient technologies and systems, including renewable energy technologies and systems, in accordance with the policies established by this Act. (*Republic Act No. 11285*, n.d.)

Incentives. Article 32(1) of Executive Order No. 226 (The Omnibus Investment Code of 1987) exempts energy efficiency projects, so they are eligible for incentives regardless of the country's ownership of the business. Incentives other than financial ones, like government technical support, may also be available to businesses undertaking EE projects (De Jesus, 2019) ;(Admin, 2022).

Green Energy Option Program. Outlined in ERC Resolution No. 08, Series of 2021, the Green Energy Option Program (GEOP) offers a structure for Philippine end users to source electricity just from renewable energy (RE) sources. Advancing sustainable energy consumption and expanding the energy mix of the nation depend on this project. Participants under GEOP must average peak demand of no less than 100 kilowatts (kW) over the past 12 months. To meet their power needs, customers could interact directly with licensed renewable energy suppliers. This clause helps big consumers to adopt eco-friendly habits, matching their energy consumption with goals of sustainability (Independent Electricity Market Operator of the Philippines [IEMOP], 2021).

Guidelines and Best Practices for Micro, Small, and Medium-sized Enterprises

The energy efficiency and renewable energy sectors have recommendations and best practices for MSMEs published by the United Nations Economic Commission for Europe (UNECE). These guidelines provide solutions to issues like poor digitization and difficulty purchasing new technology while also assisting MSMEs in implementing creative, circular, green, and sustainable activities. The publication offers suggestions and policy actions to help MSMEs in the event of the COVID-19 pandemic. Even though there are numerous funding schemes available to stabilize MSMEs, more steps are required to assist enterprises that are more susceptible. MSMEs have postponed unnecessary initiatives and adjusted to working remotely in order to lessen the impact. Reaching investors and consumers in the midst of the crisis requires a virtual presence and online activity. Offering skill-based workshops for little cost is a workable strategy, particularly in the energy efficiency industries. (United Nations Economic Commission for Europe, 2021).

Case Examples of RE Integration in Philippine MSMEs

The following examples showcase how MSMEs have successfully integrated renewable energy technologies to enhance operational efficiency, reduce costs, and promote sustainability across different sectors.

Laak Multipurpose Cooperative (Isabela) - Rice Mill Cooperative (Agriculture). Laak Multipurpose Cooperative (Isabela) runs an agricultural rice mill cooperative. To run its milling machines, a rice-farming cooperative installed a 5.1 kW solar photovoltaic system—probably off-grid. By using solar power, the mill doubled its processing capacity to 100 sacks daily from the range of 30–50 sacks. By ₱20,000 for every 1000-sack cycle, it also cuts electricity costs. By giving farmers a lower milling rate of Php 3.00/kg, the cooperative was able to raise their profits and improve the quality of rice processing. Solar energy gave this agribusiness consistent electricity and cost savings, so restoring capacity lost by typhoon damage. (McCloud, 2024).

Limulan Coffee Farmers (Mindanao) - Coffee Processing Facility (Agricultural Sector). A farmers' association set up a 16.38 kW grid-tied solar photovoltaic system to run an on-site coffee processing facility. These days, solar-powered dryers and equipment let farmers turn beans into finished (roasted/packed) coffee locally. Although it lowers running costs, this value addition raises their market selling price. Using on-grid photovoltaic systems with net-metering, the co-op harnesses clean energy for post-harvest processing, thereby lowering fuel consumption and greenhouse gas emissions (International Renewable Energy Agency [IRENA], 2023b).

Solar Sari-Sari Store. Comprising Ateneo alumni, social entrepreneurs like SolarSolutions have set up solar-powered micro-grids for off-grid small neighborhood stores, sometimes known as "sari-sari stores." With 20-foot solar panels and batteries, these containerized kiosks give store owners in far-off towns or disaster-torn areas phone charging and lighting capability. Every store serves as a fuel station, providing the community with basic needs, including mobile charging and lighting. The aim is to provide micro-retailers with access to electricity, so acting as both a public utility and a business resource in places without grid power. Though exact ROI numbers are not available, the observed result shows improved access: villagers can run businesses and charge devices after dark, so fostering local resilience and commerce (Cruz, 2016).

Cold Storage Warehouse. Estimated to cost ₱5.5 million, a cold storage warehouse close to Manila Airport installed a grid-tied rooftop photovoltaic system in 2017. The monthly Meralco bill was roughly ₱580,000 before solar was installed. After a 32 kWp photovoltaic system with net metering was put in place, the bill dropped to less than ₱480,000 and monthly savings of ₱100,000 emerged. The owner estimates that the system will pay for itself in less than five years, generating net savings of almost ₱24 million over a twenty-year period. The main goal was economic: lowering high electricity costs, especially related to refrigeration loads, improves profitability. The outcome is a fast return on investment and a roughly 17% bill reduction (Si & Si, 2019).

Greenhouse Café Clark. The 45 kW solar farm, a component of the Sustainability Garden at this restaurant in Clark Freeport shown in Figure 1, provides electricity to both the restaurant and the electric vehicle (EV) charging stations, positioning Greenhouse Café as an additional EV charging station in Clark Pampanga (GreenHouse Cafe Clark, 2024b).

Figure 1. Greenhouse Café Solar Garden, Clark, Pampanga.
(Source: GreenHouse Cafe Clark, 2024a)

Qi Palawan (El Nido Resort). Operating totally on solar power, Qi Palawan is a boutique resort offering a complete air-conditioned facility. Sustainability and energy independence drove the adoption; Qi Palawan offsetting almost 996 metric tons of CO_2 yearly is equivalent to the effect of tree planting. While the resort bills itself as an eco-resort run totally on renewable energy sources, guests get ongoing service free from fuel costs. Figure 2 shows solar PV installed along with 128 kWh of battery storage, a 40 kW photovoltaic array creates a hybrid/off-grid system free of diesel generators. Now covering lighting, air conditioning, and hot water, solar panels meet the resort's entire power needs around the clock (Tatler, 2021).

Figure 2. Qi Palawan Resort (Source: WazzupPilipinas.com, n.d.).

Basic Energy Efficiency Measures and Technologies

A variety of practical techniques and technology exist to assist MSMEs in enhancing energy efficiency, reducing operational expenses, and promoting environmental sustainability.

Switching to LED lighting. LED lights use about 75% less energy than traditional incandescent bulbs and last up to 25 times longer, significantly reducing both energy consumption and replacement costs (SimplyLED, 2024).

Implementing power management settings. Using power management features on computers, such as setting monitors and hard drives to power down after periods of inactivity and enabling sleep modes, can save up to $50 annually per device and reduce environmental impact by lowering electricity use (Western Michigan University, n.d.).

Regular maintenance of equipment. Routine maintenance, such as cleaning HVAC filters, inspecting ductwork, and lubricating machinery, ensures equipment operates efficiently and can reduce energy consumption by 15-20%, depending on the system (Crager, 2024).

Using energy-efficient appliances. Appliances with ENERGY STAR certification are significantly more energy-efficient: refrigerators use 9% less energy, washing machines use 25% less energy and 33% less water, and dryers can collectively save $1.5 billion in utility costs annually if widely adopted. (Presto, 2023)

Optimizing HVAC systems. Energy efficiency in HVAC systems is crucial for reducing power consumption in buildings, which account for over 40% of total energy use in many developed countries (Jouhara & Yang, 2018). Maintenance strategies play a significant role in achieving energy efficiency, with three main approaches identified: inspection-based maintenance (IBM), time-based maintenance (TBM), and condition-based maintenance (CBM) (Firdaus et al., 2023). IBM relies on human senses to detect energy faults and uses payback period analysis for decision-making. CBM monitors energy performance indicators and employs diagnostics or prognostics approaches to identify and address energy degradation. TBM utilizes historical data and deterioration modeling to determine optimal maintenance timing. These strategies can be applied as energy conservation measures in implementing the ISO 50001 energy management systems standard, bridging the gap between research and industry practices (Firdaus et al., 2023). Proper maintenance strategies contribute to enhancing the efficiency of HVAC systems and their components (Jouhara & Yang, 2018).

Adopting renewable energy sources. Solar panels provide a renewable, clean source of electricity that reduces reliance on grid energy and does not produce emissions during operation. Solar energy is the fastest growing and most abundant renewable energy source globally (Wigness, 2023).

Implementing energy monitoring systems. Real-time energy monitoring tools help organizations identify inefficiencies, reduce waste, and optimize operations, typically resulting in energy cost savings of 5-20% and improved equipment performance (Fuh, 2024).

Encouraging behavioral changes. People who are only familiar with a small number of "behavior change programs," such as home energy reports, which lower consumption by an average of 1% to per each family, may find it difficult or perhaps impossible to achieve a 63% reduction in energy usage through behavior change (American Council for an Energy-Efficient Economy, 2023)

Upgrading to high-efficiency motors and drives. Recalculating stator windings and using current ferro-resonance among innovative upgrading methods can help to improve power factors and efficiency, so lowering active power losses by 3-7% (Mugalimov et al., 2020). Usually paying for themselves with energy savings over 0.25 to 0.8 years, these improvements with almost half of all electricity consumed worldwide coming from electric motor systems, there are clear chances for efficiency gains (de Almeida et al., 2024). Further promises for energy savings comes from advanced technologies including digitalization, regenerative drives, and silicon-carbide variable-speed drives. Adoption of high-efficiency motors and motor-driven systems widely could result in worldwide energy savings of up to 1000 TWh/year (de Almeida et al., 2024), helping to slow down climate change.

Conceptual Framework

This paper develops comprehensive energy profiles, increased awareness of energy efficiency and conservation, and energy efficiency alternatives by recommending a renewable energy technology setup using an Input-Process-Output (IPO) paradigm. Data on energy usage, information on current energy efficiency management strategies, and surveys with MSME owners and experts comprise the inputs that the framework starts with. These inputs support the procedures of data analysis, energy audits, and profiling. The intended results of lower energy costs, improved sustainability, and higher MSMEs' competitiveness are thus attained via these outputs.

As shown in Figure 3, this study starts with the collection of estimated data on energy consumption based on equipment usage through survey and site visit. Surveys, document analysis, and structured questionnaires are used to collect more data. This study used a combination of pre- and post-surveys to measure the growth in awareness regarding energy efficiency among MSMEs in Ilocos Norte. In order to provide a baseline of energy management-related knowledge, attitudes, and practices, standardized questionnaires were first distributed. Results from the pre- and post-survey were compared to show increases in awareness through changes in behavior, attitudes, and knowledge. The data analysis led to the recommendation of the solar PV setup as an energy-efficient alternative, giving MSMEs the option to adopt the setup if they decide to do so.

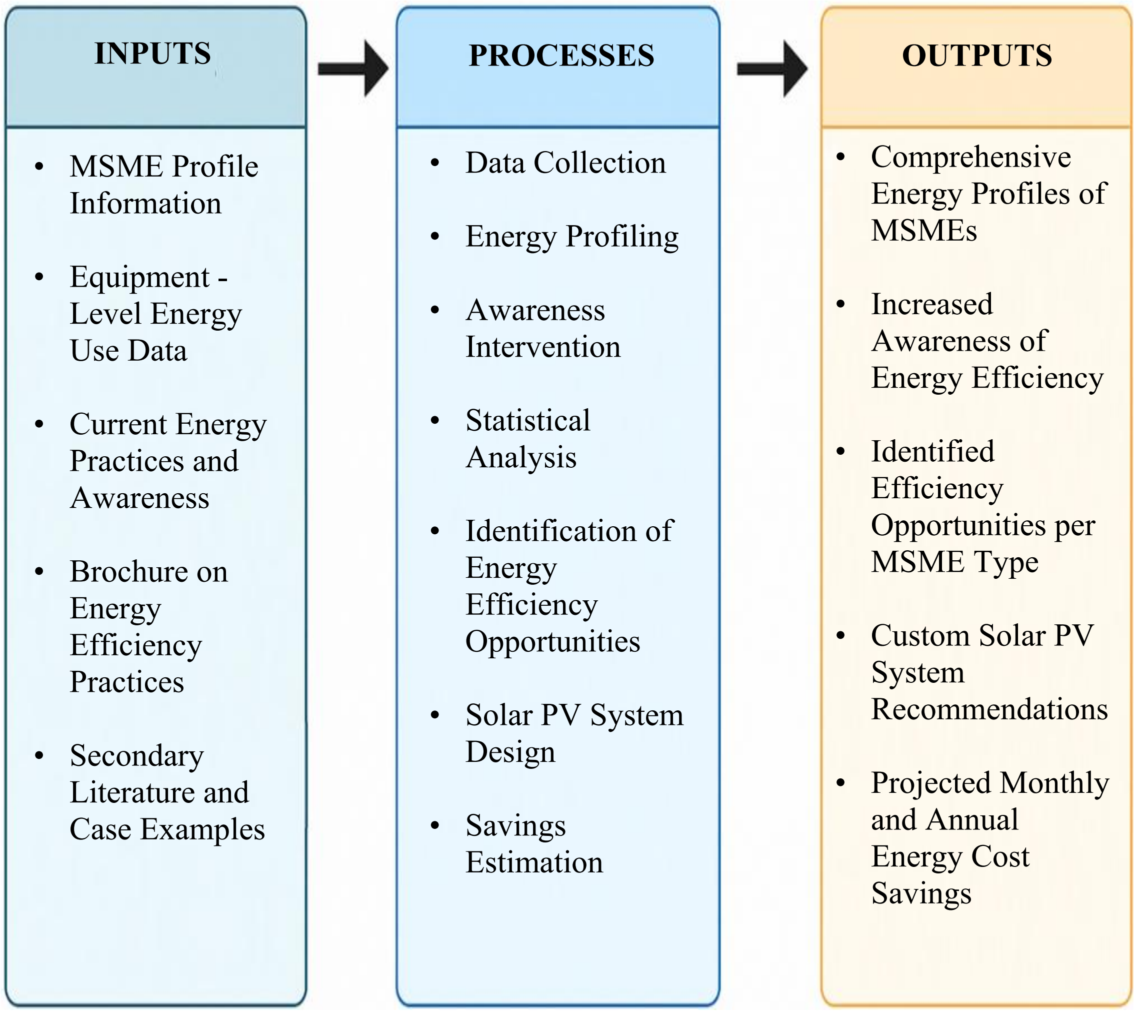

Figure 3. IPO-Based Framework for Energy Profiling and Efficiency Enhancement in MSMEs

CHAPTER III

METHODOLOGY

This chapter presents the locale of the study, respondents in the study, research methods and tools used, data collection instruments, and data collection, analysis, and interpretation.

Locale of the Study

The study was conducted in Ilocos Norte, a province in Northern Luzon, Philippines. It focused on selected micro, small, and medium-sized enterprises (MSMEs) from multiple municipalities operating within the province to reflect a broad spectrum of business categories and operational scales.

Respondents in the Study

Figure 4 shows the municipalities of selected MSME respondents in the study. Applying Slovin's formula to the province's 22,490 registered MSMEs (21,735 micro, 517 small and 178 medium) and setting a 10 percent margin of error produced a target sample of about 100 participants. Accordingly, the study purposively selected MSME owners, managers, and technical staff from across Ilocos Norte's micro, small and medium-sized firms. They were chosen because they are the people who oversee daily operations and energy use. Their participation was voluntary, informed-consent forms were obtained, and responses were kept anonymous and securely stored. Personal information such as names, age, and business name is optional.

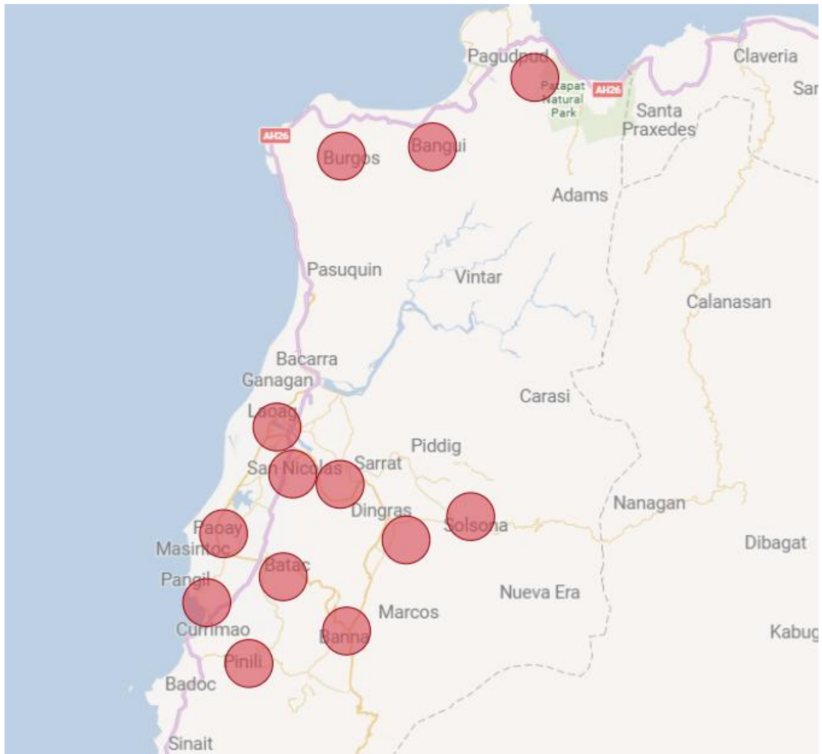

Figure 4. Geographic Distribution of Respondent MSMEs Across Selected Municipalities in Ilocos Norte.

Research Methods and Tools Used

A mixed-methods approach was adopted, integrating both quantitative and qualitative data collection. Quantitative data focused on estimating energy consumption patterns, while qualitative data explored the awareness, attitudes, and practices of MSMEs toward energy efficiency. This dual approach enabled a more comprehensive understanding of energy usage across different types of enterprises.

Data Collection Instruments

A standardized survey form and brochure were employed to collect and distribute pertinent data.

Survey form. The instruments used for data gathering included a structured survey form (See Appendix B). For the quantitative part, respondents were asked to provide estimates of their energy consumption based on their equipment's wattage, usage hours per day, and number of units. For the qualitative part, open- and close-ended questions embedded in the survey explored other energy-saving practices, awareness levels, and perceived barriers to energy efficiency. The survey form questionnaire has also undergone University Research Ethical Review Board (URERB) clearance (See Appendix A).

Brochure. A brochure was created by consolidating established energy efficiency practices, aiming to increase awareness among participants shown in Figure 5.

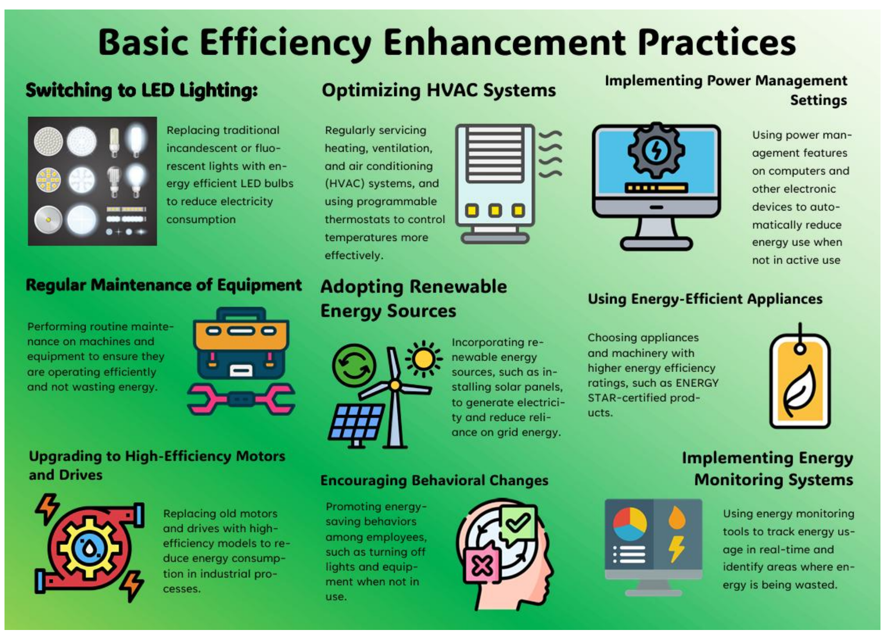

Figure 5. Basic Efficiency Enhancement Practices Brochure.

The objective was to offer accessible and practical guidance specifically designed for micro, small, and medium enterprises (MSMEs), facilitating their comprehension and implementation of energy-saving measures in operations. The content was curated from credible sources to ensure relevance and applicability, serving as foundational learning material during the intervention phase of the study.

Data Collection, Analysis, and Interpretation

Data was collected online or in person, depending on respondent preference and availability. The respondents provided information on how they use their equipment and how much electricity they expect to use each month. Descriptive data, like the mean, were used to compile energy use by type of equipment.

The total operating hours in an average month were estimated by multiplying the firm's reported average hours of operation per day by the number of business days in a week, scaling it to a seven-day week, and then multiplying the result by 30. An estimated monthly energy consumption was calculated by multiplying the daily electricity use, measured in kilowatt-hours, by the same monthly business-day factor. Each MSME's energy intensity value in kWh was obtained by dividing this monthly kWh amount by the corresponding monthly hours.

To evaluate any changes in attitudes or knowledge about energy efficiency, surveys were conducted both before and after the awareness campaign. After completing the reading material included with the survey form, respondents are given a post-test. The survey is accompanied by a brochure or information outlining basic energy efficiency techniques. A paired t-test was used to assess any statistically significant changes in awareness between before and after the information campaign. Energy profiles and potential areas for improvement were generated by the study by identifying which basic energy practices applied to their business.

Based on the information acquired, a personalized recommendation for a solar PV system was given to each participating MSME. The system size in kilowatts (kWp) was calculated using the formula below:

$$Suggested\ Solar\ Size\ (kW)\ =\frac{Daily\ Energy\ Use\ (KWH)}{Peak\ Sun\ Hours}x1.30$$

This model assumed a local average of 3.5 peak sun hours per day and included a 30% buffer to account for system losses. If the business operated after hours, the amount of battery storage required was also calculated using:

$$Battery\ Capacity\ (Ah)\ =\frac{Daily\ Usage\ (KW)\ x\ 1000}{System\ Voltage}$$

To assess and confirm the technical feasibility of each proposed configuration, the calculated solar PV system parameters were simulated utilizing PVsyst software. Inverters and PV modules present in the software's database were employed to ascertain viable string configurations and inverter compatibility.

The PVWatts Calculator, developed by the National Renewable Energy Laboratory (NREL) of the U.S. Department of Energy, was used to analyze the estimated energy savings from the suggested PV system configurations. Considering the geographic and climatic conditions of Ilocos Norte, Philippines, the simulation tool calculated the monthly AC energy output for each proposed solar PV system capacity. (*PVWatts - NREL*, n.d.)

In order to maximize the reception of solar irradiance, the system parameters were set up to resemble a typical installation: fixed roof-mounted array, standard module type, 20-degree tilt, and 180-degree azimuth. A DC-to-AC size ratio of 1.2, an inverter efficiency of 96%, and system losses of 14.08% were among the other technical requirements. The ground coverage ratio and bifacial settings were left at their default settings. The coordinates of Ilocos Norte (latitude 18.21°, longitude 120.58°) at an elevation of 10 meters were used in the location input. Irradiance losses per month were deemed insignificant, suggesting consistent and ideal solar availability throughout the year.

The PVWatts calculator was used to enter the corresponding DC capacity in kilowatts for each recommended system size. The study was able to determine the average monthly output because the tool generated monthly estimates of AC energy production. To calculate the possible monthly cost savings for each setup, the average was then multiplied by PHP 11 per kilowatt-hour, which represents the assumed prevailing electricity rate.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter provides an analysis and explanation of the data collected from micro, small and medium enterprises in Ilocos Norte.

Demographics of MSME Respondents

Despite the original goal, the study ended up involving 129 respondents, including 113 micro, 13 small, and three medium-sized MSMEs, as shown in Figure 6. The surprisingly high participation rate allowed for wider representation across multiple MSME categories and improved the findings' reliability. The dataset was improved, and a more thorough understanding of energy usage trends and efficiency opportunities within the MSME sector of Ilocos Norte was provided by the slight oversampling.

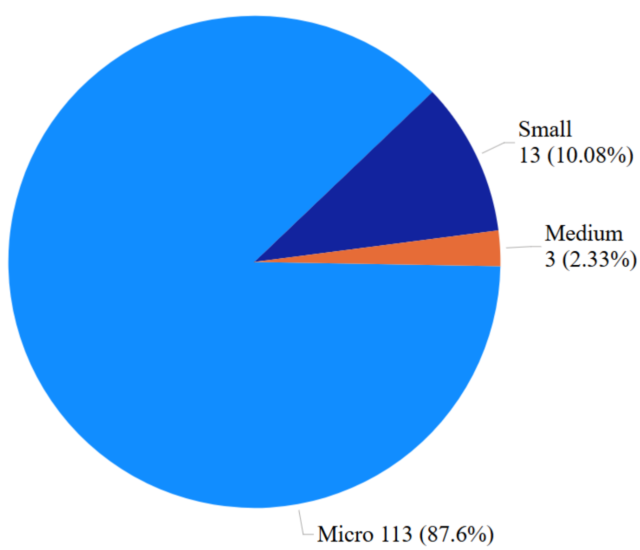

Figure 6. Respondents per Business Category.

The gender distribution of MSME respondents, illustrated in Figure 7, reveals a marginally greater involvement of female business owners or managers, comprising 71 respondents (55.04%), in contrast to 58 male respondents (44.96%). This balanced representation indicates a significant presence of women in the entrepreneurial landscape of Ilocos Norte and underscores the necessity of inclusive energy efficiency strategies that cater to the needs of both male- and female-led enterprises.

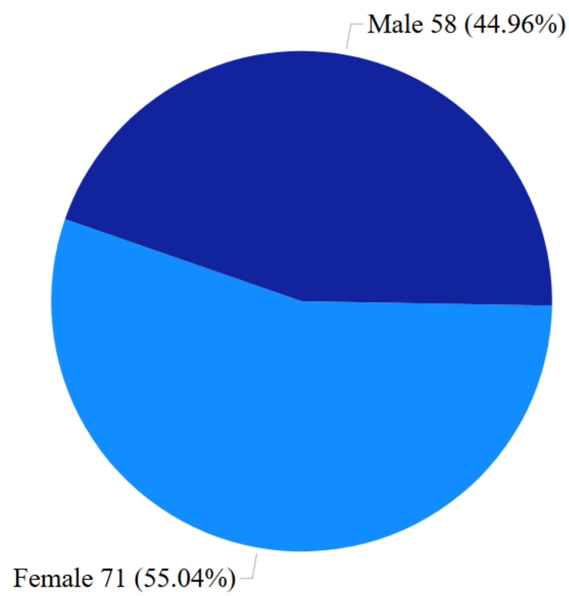

Figure 7. Respondents per Sex Aggregation.

The distribution of respondents by industry type, as illustrated in Figure 8, indicates a predominance in the retail and food and beverages sectors. Retail businesses represented the largest category, accounting for 52 MSMEs (40.31%), highlighting the dominance of small stores and commercial establishments throughout the province. A total of 41 respondents (31.78%) were from the food and beverages sector, encompassing establishments such as eateries, bakeries, and similar businesses that rely significantly on refrigeration and cooking equipment.

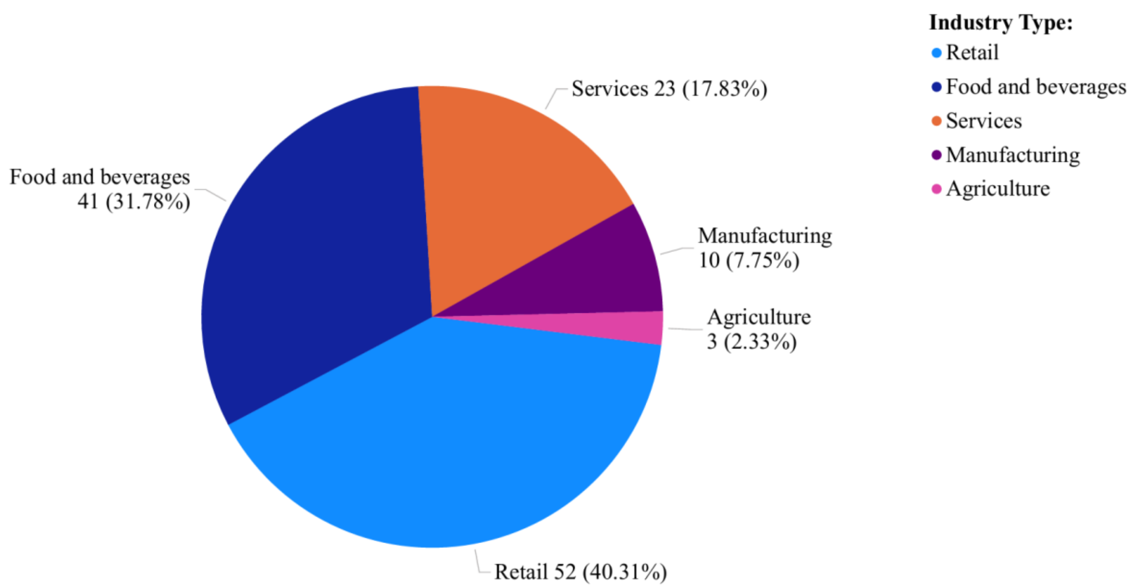

Figure 8. Respondents per Industry Type.

The services sector occupied the third position, comprising 23 businesses (17.83%) that include salons, repair shops, and internet cafés, most of which exhibit stable yet moderate energy consumption. Manufacturing comprised 10 respondents (7.75%), indicating a reduction in number but an increase in energy intensity among enterprises. Finally, the agriculture sector represented the smallest proportion, comprising only three MSMEs (2.33%), likely attributable to its seasonal characteristics or minimal dependence on electricity.

The distributions highlight the prevalence of energy-dependent sectors with consistent operations and emphasize the necessity of addressing gender and industry-specific requirements in developing effective energy efficiency enhancements and investigating renewable energy integration among MSMEs in Ilocos Norte.

Electricity Consumption Profiles of Selected MSMEs

Each categorical survey response of 129 respondents was first converted to a single midpoint value in order to convert it into useful numbers. While any response that said "more than four" was standardized to five units, precise counts of one to four were maintained as 1, 2, 3, and 4. Less than one hour was represented by 0.5 hours, one to two hours by 1.5 hours, three to four hours by 3.5 hours, five to eight hours by 6.5 hours, and more than eight hours by nine hours for the daily hours of use. These midpoint values were used to calculate consumption by equipment type using the formula units × hours × watts ÷ 1000. This resulted in an estimated kilowatt-hours per day, which could be averaged across respondents to show the mean load contribution per equipment type. The energy consumption of various equipment types across micro, small, and medium-sized enterprises (MSMEs) is compiled in Table 2.

Table 2. Current electricity consumption of selected MSMEs based on equipment.

Equipment	Daily Usage (kWh)			
	Micro	**Small**	**Medium**	**Mean per Equipment**
Cooling & Ventilation (Electric Fans, Air Conditioners, Exhaust Fans, Air Purifiers, Dehumidifiers)	1.53	4.07	19.24	2.19
Entertainment & Audio Equipment (Speakers, Amplifiers, Microphones, LED Display Panels, CCTV Systems)	0.44	0.68	18.11	0.87
Industrial & Manufacturing Equipment (Electric Drills, Grinders, Welding Machines, Compressors, Conveyor Belts, Vacuum Sealers, Industrial Mixers)	1.62	0.02	14.45	1.76
Kitchen Equipment (Rice Cookers, Electric Stoves, Induction Cookers, Microwaves, Ovens, Toasters, Coffee Makers, Blenders, Food Warmers, Juicers)	0.99	0.91	3.61	1.04
Lighting & Electrical Fixtures (LED Bulbs, Fluorescent Lamps, Emergency Lights, Outdoor Signage, Neon Lights)	1.85	2.61	14.25	2.21
Office & IT Equipment (Computers, Monitors, Printers, Scanners, Photocopiers, Routers, Modems, Cash Registers, POS Machines, Televisions, Projectors)	1.17	0.23	18.01	1.46
Refrigeration & Storage (Refrigerators, Freezers, Water Dispensers)	4.28	3.34	7.58	4.26
Other Electrical Appliances	1.36	0.20	18.00	1.63
Mean (kWh)	**13.32**	**12.07**	**113.25**	**15.43**

Due to their larger operations, medium-sized businesses typically use the most energy, particularly in areas like refrigeration, industrial machinery, and cooling and ventilation. Figure 9 shows the three most used equipment groups.

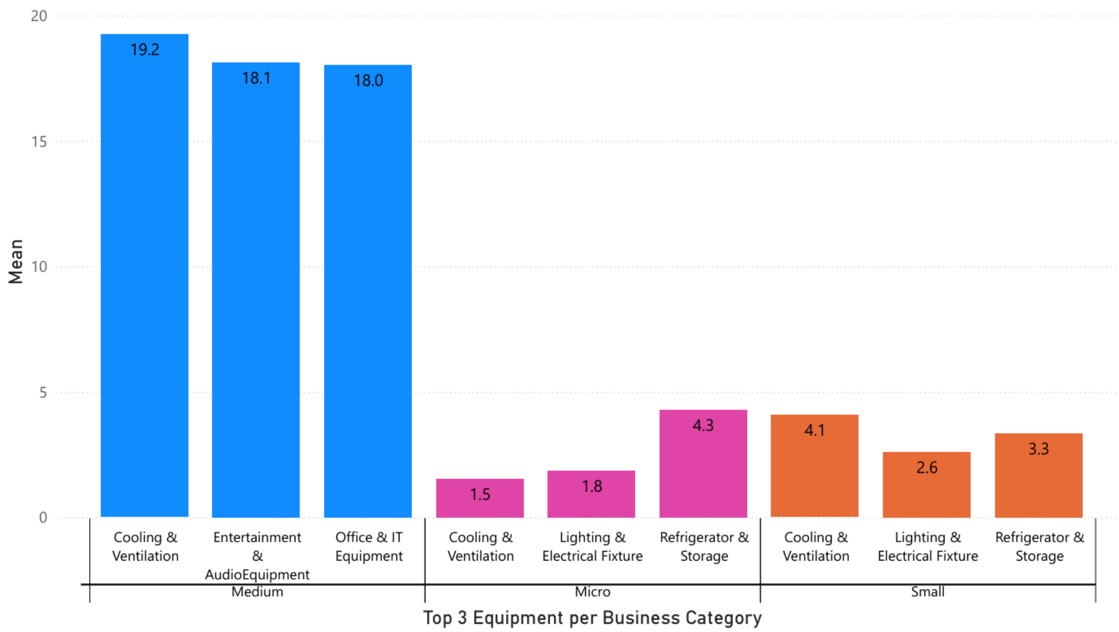

Figure 9. Top 3 Equipment Usage per Business Category.

While cooling and ventilation equipment shows the highest average daily use, especially for medium-sized companies, refrigeration shows the highest average daily use overall. However, due to their smaller operations and lower equipment requirements, micro and small businesses use a lot less energy in most categories. The average daily energy consumption for all equipment types is 15.43 kWh, and high-energy-demanding categories like cooling and refrigeration show where MSMEs could concentrate on energy efficiency.

This information emphasizes how urgently MSMEs—especially medium-sized businesses—should look at sustainable energy solutions, including specific energy efficiency strategies and solar photovoltaic (PV) systems. Since peak energy demand usually corresponds with peak sunlight availability, high-consumption sectors like refrigeration and cooling offer great chances for the integration of solar photovoltaic systems. By means of solar PV systems, MSMEs can greatly lower their daily energy consumption, lower running costs, and improve energy resilience. Energy efficiency interventions can greatly lower consumption and increase sustainability by means of upgrading to inverter-based equipment, enhancement of insulation, and optimization of usage schedules. The techniques directly complement the goals of the research, which aimed to help MSMEs in Ilocos Norte implement more affordable and effective energy solutions.

Energy Intensity and Usage Patterns

To analyze the energy demand behavior of MSMEs, an energy intensity metric was calculated by dividing the total monthly energy consumption of equipment by the total operational hours for that month. This led to an average kilowatt load per hour of operation, reflecting the power consumption of the equipment during use. The process of calculating this metric started with the schedules of 129 respondents. Four performance bands were then created from these scores: "Lowest" (less than 14.77 kWh), "Moderate" (14.77–29.52), "High" (29.53–44.28), and "Highest" (44.29 kWh and above), as shown in Table D1 (Appendix D) and Figure 10.

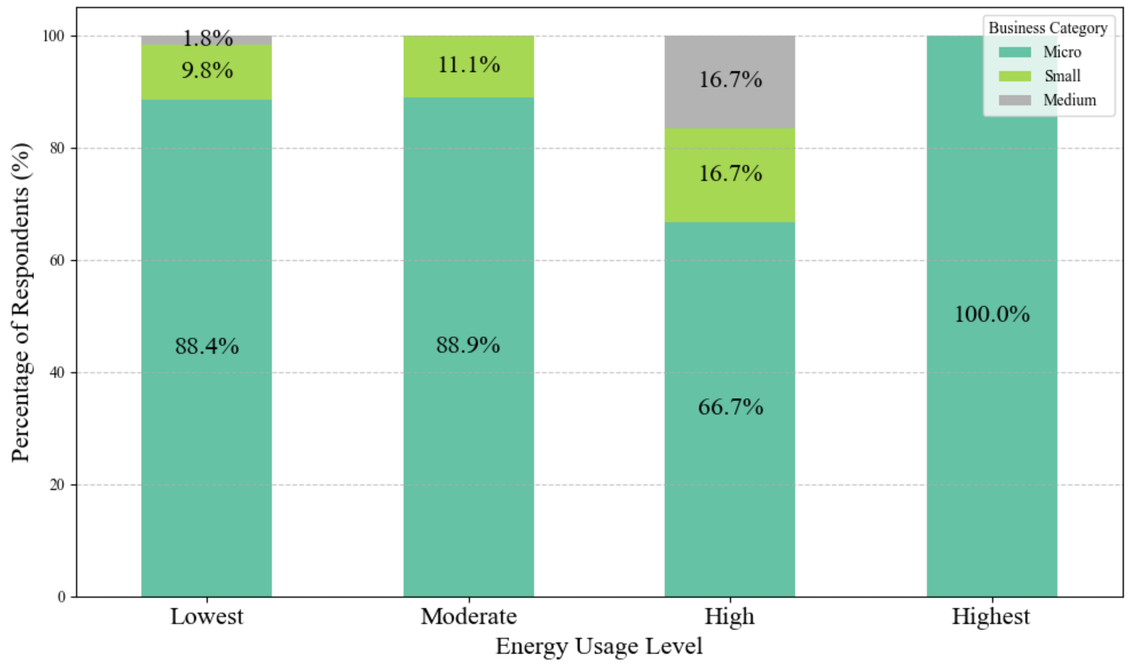

Figure 10. Energy Intensity by Business Category.

Micro-enterprises make up the majority of the dataset and exhibit a wide range of energy consumption patterns, according to the analysis of energy intensity classifications. Ninety-nine of the 112 microenterprises, or 88.4% fall into the "lowest" energy intensity category, indicating that they use very little energy. This could be because they have smaller operational scales, fewer pieces of equipment, or fewer hours of operation. Only a small percentage of micro-enterprises have high levels of consumption (9 classified as "moderate," 5 as "high," and 2 as "highest" energy intensity). This suggests that even though most microbusinesses use little energy, a small percentage might use equipment or carry out specialized, energy-intensive tasks, especially in sectors like food processing or cold storage. Eleven of the thirteen small businesses are categorized as having the "lowest" energy intensity, one is categorized as "moderate", and one also categorized as "high." This implies that even though small businesses typically have more operational space than microbusinesses, they might still use systems that are comparatively efficient or operate in industries with lower energy consumption.

Despite having only three respondents, medium-sized businesses show a similar trend. One is in the high range, and two are in the lowest category. Despite their possibly larger operational scale, two of the medium-sized businesses may be implementing more efficient practices or technologies to mitigate excessive energy consumption, as no entities fall into the high or highest energy intensity brackets.

Operating profiles of MSMEs falling within the high and highest energy intensity ranges were most exacting. These facilities reported seven-day-a-week operating schedules, with daily operational hours ranging from seven to twenty-four, producing the highest average daily kilowatt-hour (kWh) consumption. Long stretches of activity show a clear reliance on electricity for basic business operations including refrigeration, food preparation, machinery running, and lighting. These elements cause increasing energy expenses and slowdown of equipment.

These results highlight the need to improve energy efficiency plans and include renewable energy sources in these businesses. While keeping production levels, the use of energy-efficient appliances, lighting systems, and maintenance procedures can significantly lower energy usage. Especially solar photovoltaic (PV) systems, the use of renewable energy sources offers a practical way to lower daytime energy consumption and dependency on conventional grid electricity. These measures improve the operational resilience and environmental responsibility of energy-intensive MSMEs by aligning with more general sustainability goals and offering long-term economic gains.

Weekly Energy Consumption by Sector

Figure 11 shows that from Monday to Saturday, the agriculture sector showed a constant daily energy consumption of 14.61 kWh, suggesting steady operations. However, consumption dropped to 0.00 kWh on Sunday, indicating a complete stop of activity. This is most likely due to standard non-working policies or less demand during weekends. The consistent trend shows very little change in working conditions during the week.

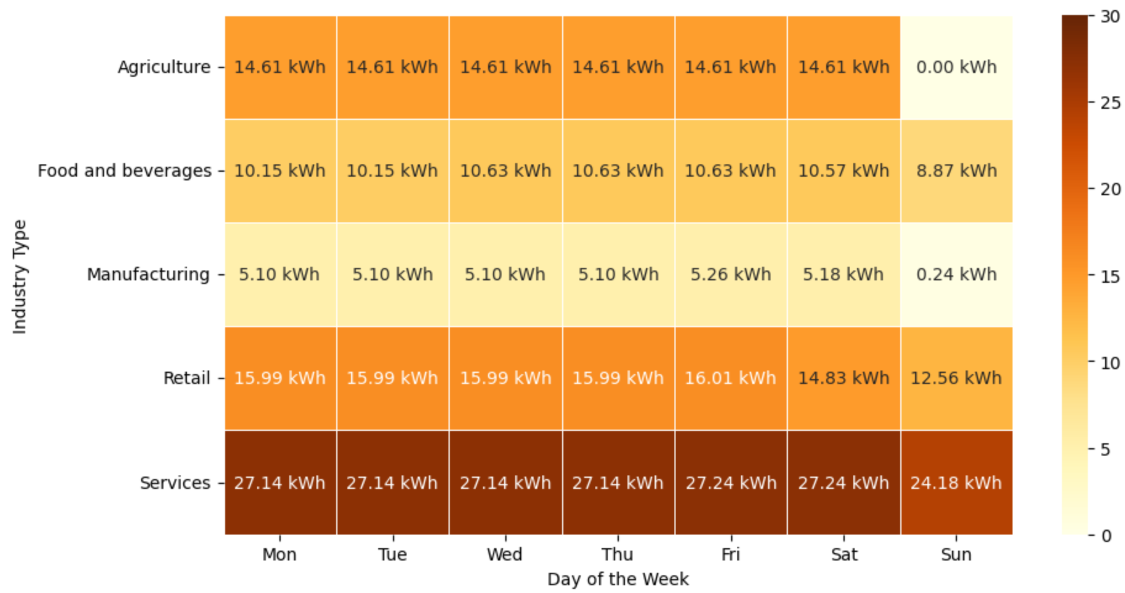

Figure 11. Average Daily Electricity Consumption (kWh) of MSMEs by Industry and Day of the Week

(*Note: Values marked as 0.00 kWh indicate either non-operational days (e.g., Sundays for agriculture) or lack of reported consumption data for that specific day. These should not be interpreted as energy efficiency indicators.*)

Beginning on Monday and Tuesday at 10.15 kWh and rising somewhat to 10.63 kWh from Wednesday to Friday, the food and beverages sector showed minor variations in energy consumption, then declining to 10.57 kWh on Saturday and 8.87 kWh on

Sunday. This trend can be explained by mid-week production surges brought on by higher client demand; operations drop on weekends when businesses might cut hours or see fewer customers.

With Monday through Thursday registering 5.10 kWh, a slight increase to 5.26 kWh on Friday and Saturday, and then a notable decline to 0.24 kWh on Sunday, the manufacturing sector showed the lowest energy use among all MSME groups. This trend suggests a normal five- or six-day workweek, with factories or industrial sites greatly cutting or stopping operations on weekends.

Reflecting the manufacturing trend, the retail sector kept an energy consumption of 15.99 kWh Monday through Thursday, rose little to 16.01 kWh on Friday, then dropped to 14.83 kWh on Saturday and 12.56 kWh on Sunday. This variation is most likely related to increased commercial activity all through the workweek, peaked on payday Friday, and declined as stores cut their operation hours or see less customer traffic over the weekend.

Using 27.14 kWh Monday through Thursday, increasing slightly to 27.14 kWh on Friday and Saturday, and then dropping to 24.18 kWh on Sunday, the service sector reported the highest total energy usage. Although the small drop on Sunday still indicates significant activity, perhaps related to critical or appointment-based services running over the weekend, the minimal variation during weekdays indicates continuous client service.

The services and rental sectors have the highest and most consistent usage, likely due to daily operational demands. Retail and F&B drop on weekends, implying consumer-facing demand shifts. While agriculture and manufacturing show minimal to zero Sunday operations, which supports the idea of rest days or lower automation.

Correlation Between Operating Hours and Energy Use

The daily operating hours and electricity consumption (kWh) have a moderately positive relationship, according to the scatter plot and Pearson correlation analysis. With a p-value of 0.001974 and a Pearson correlation coefficient of $r = 0.27$, the results showed statistical significance at the 0.01 level. In general, daily electricity consumption rises in tandem with longer operating hours. Operating hours are not a good indicator of energy consumption, according to the low correlation coefficient, which suggests that other factors like industry category or equipment type have a bigger impact on energy use. Figure 12 shows the relationship between operation hours and daily energy usage of 129 respondents

A few outliers, most notably one MSME that recorded a maximum daily usage of 330.6 kWh, exceeding the mean, have an impact on the average daily electricity consumption of 15.43 kWh. The majority of MSMEs, on the other hand, appear to consume little energy, which may be related to their shorter operating hours or less energy-intensive operations, as 50% of respondents reported daily consumption of no more than 2.45 kWh. A mean of 10.1 hours per day and a standard deviation of 3.8 hours were found in the operational hours analysis, indicating considerable variation in the amount of time MSMEs spend operating each day.

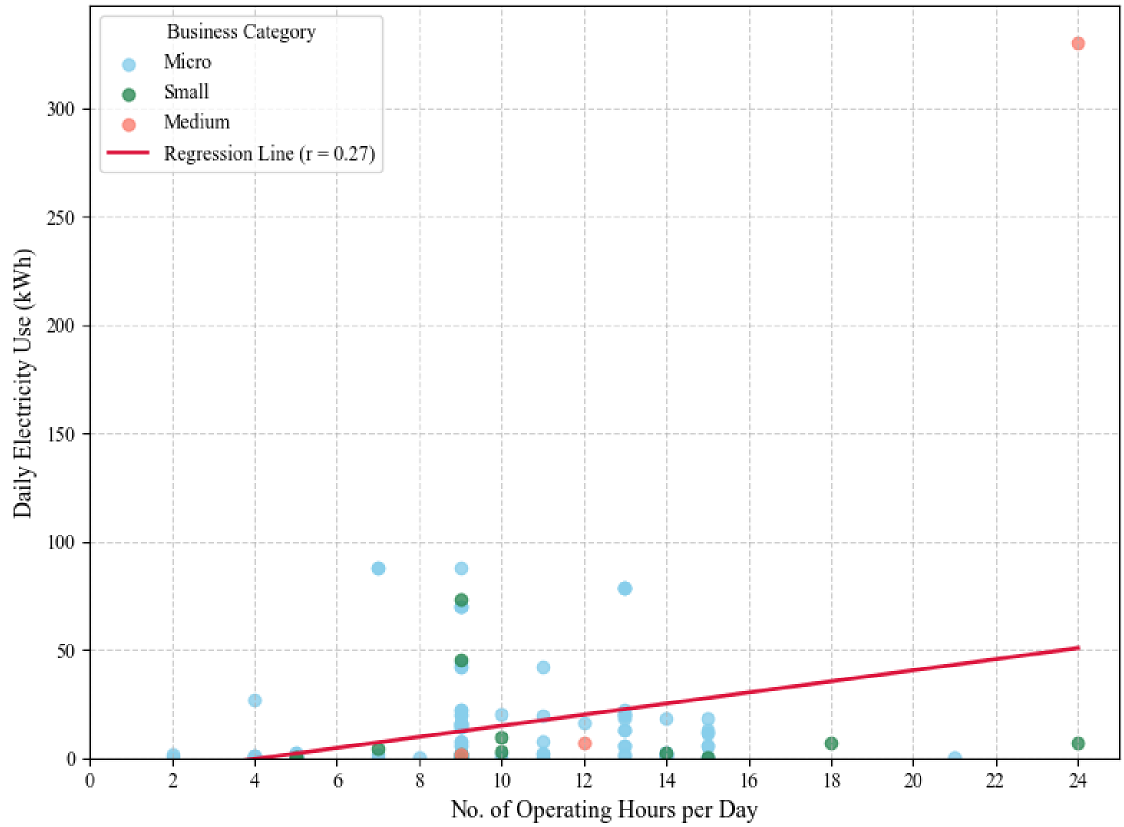

Figure 12. Relationship between Operation Hours and Daily Energy Usage.

The fact that some only run for an hour and others for up to 24 hours shows how different business operations can be. Since longer hours do not always translate into higher energy consumption—especially when energy-efficient equipment is used or when operations are not energy-intensive (e.g., administrative services)—this variability impacts the correlation's weak-to-moderate strength.

Given this variation, especially in high-consumption outliers, it is imperative to advocate energy-efficient behaviors. Especially solar photovoltaic (PV) systems, interventions should give these businesses top priority by updating energy-efficient appliances and investing in renewable energy technologies.

Pre- and Post-Awareness Intervention Results

Descriptive scales—"Aware," "Somewhat Aware," and "Not Aware"— and the like—were first used to assess the participants' awareness of several energy efficiency improving strategies. These responses were scored analytically: 3 for "Aware," 2 for "Somewhat Aware," and 1 for "Not Aware." and the like. For 129 participants, this conversion allowed a quantitative comparison of awareness levels before and after the awareness intervention. Surveys were administered prior to and following the awareness campaign to assess changes in attitudes or knowledge regarding energy efficiency. The intervention involved a concise educational brochure integrated into the survey form, detailing fundamental energy efficiency practices, including appropriate appliance usage, behavioral strategies for reducing energy consumption, and the advantages of utilizing efficient equipment. Participants were directed to review the material prior to completing the post-test, facilitating an immediate evaluation of learning improvements subsequent to the self-directed, written intervention.

Among the evaluated core efficiency-improving strategies were: Switching to LED Lighting, Implementing Power Management Settings, Regular Maintenance of Equipment, Using Energy-Efficient Appliances, Optimizing HVAC Systems, Adopting Renewable Energy Sources, Implementing Energy Monitoring Systems, Encouraging Behavioral Changes, and Upgrading to High-Efficiency Motors and Drives.

Among the results, the switch to LED lighting stood out for its pre-test mean of 2.50 and for the notable increase in post-test awareness of 0.46 points, which suggests that even well-established methods can gain from more attention. Adoption of renewable energy sources showed the most overall increase, with a 1.02-point rise indicating a clear shift in respondents' acceptance of renewable technologies as practical substitutes shown in Table 3.

Regular maintenance of equipment showed the least change, rising by just 0.25 points. The finding suggests that, even if maintenance is a well-known idea, there could be a view that current methods are sufficient or that their more energy-saving benefits are not acknowledged.

Energy monitoring systems, energy-efficient appliances, HVAC system optimization, and encouragement of behavioral changes were among the additional practices that showed positive changes in awareness and helped toward the overall goal of encouraging energy-efficient behaviors among MSMEs.

Table 3. Mean of increased awareness.

Basic Efficiency Enhancement Practices	**Pretest Test Mean**	**Post Test Mean**	**Increased Awareness**
Switching to LED Lighting	2.50	2.95	**0.46**
Implementing Power Management Settings	1.90	2.32	**0.42**
Regular Maintenance of Equipment	2.36	2.61	**0.25**
Using Energy-Efficient Appliances	2.45	2.91	**0.46**
Optimizing HVAC Systems	1.92	2.32	**0.40**
Adopting Renewable Energy Sources	1.87	2.89	**1.02**
Implementing Energy Monitoring Systems	2.19	2.67	**0.49**
Encouraging Behavioral Changes	2.51	2.86	**0.35**
Upgrading to High-Efficiency Motors and Drives	2.05	2.40	**0.34**

Table 4. Awareness score.

	Score	**Mean**	**Standard Deviation**
Pre-test	2548	19.71	4.92
Post-test	3087	23.91	3.89

Pre-test and post-test awareness ratings shown in Table 4 were used in a paired sample t-test to ascertain whether respondents' awareness significantly changed following the intervention. Whereas the pre-test mean was 19.71 with a standard deviation of 4.92, the post-test mean rose to 23.91 with a lowered standard deviation of 3.89. With a t-statistic of 9.4379 and a p-value of <0.001, the paired t-test showed a statistically significant difference between the two score sets. A p-value much below the accepted 0.05 indicates that the intervention raised respondents' awareness of energy efficiency techniques effectively.

The observed change in the displayed bell curves visually confirms the statistical result that participants' average awareness and comprehension rose after the intervention. The distribution after the test turned noticeably to the right shown in Figure 13.

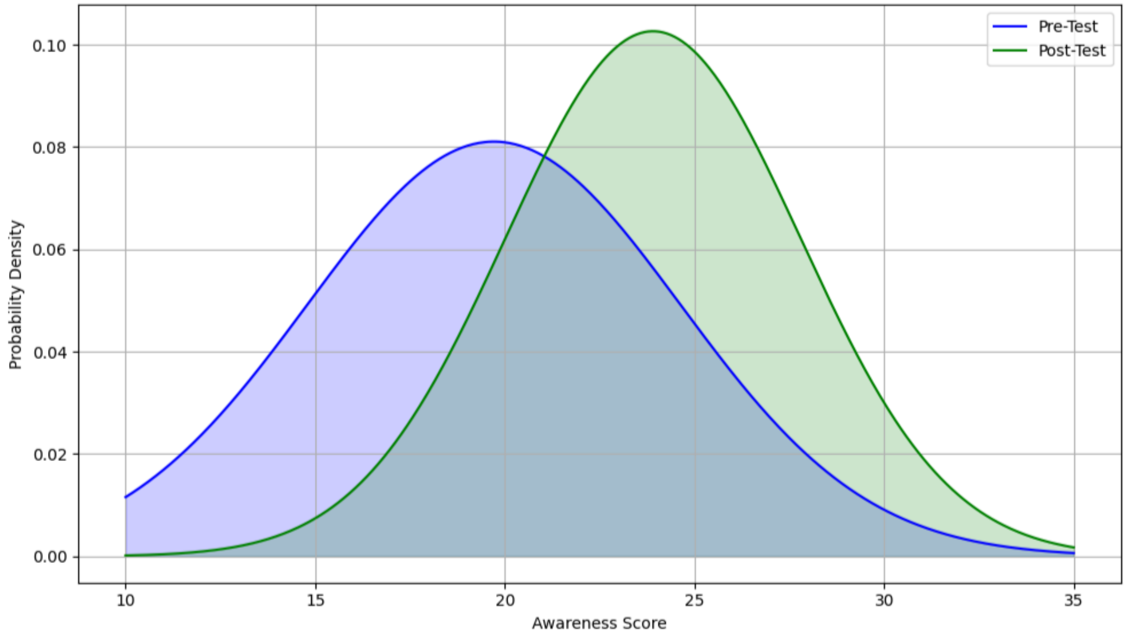

Figure 13. Awareness Score Distribution of Pre-test and Post-test.

Figure 14 illustrates the average enhancement in energy efficiency awareness levels among various business categories—micro, small, and medium enterprises—subsequent to the educational intervention.

Conversely, small businesses started with a somewhat higher mean pre-test score of 20.62 but noted a mean increase of 3.92 points. This could show differences in interest or relevance of the material to their particular operations, or it could show that small businesses already had a modest degree of awareness, producing a somewhat reduced margin for growth.

With a mean pre-test score of 20, medium businesses had the highest mean increase among the three categories—5 points.

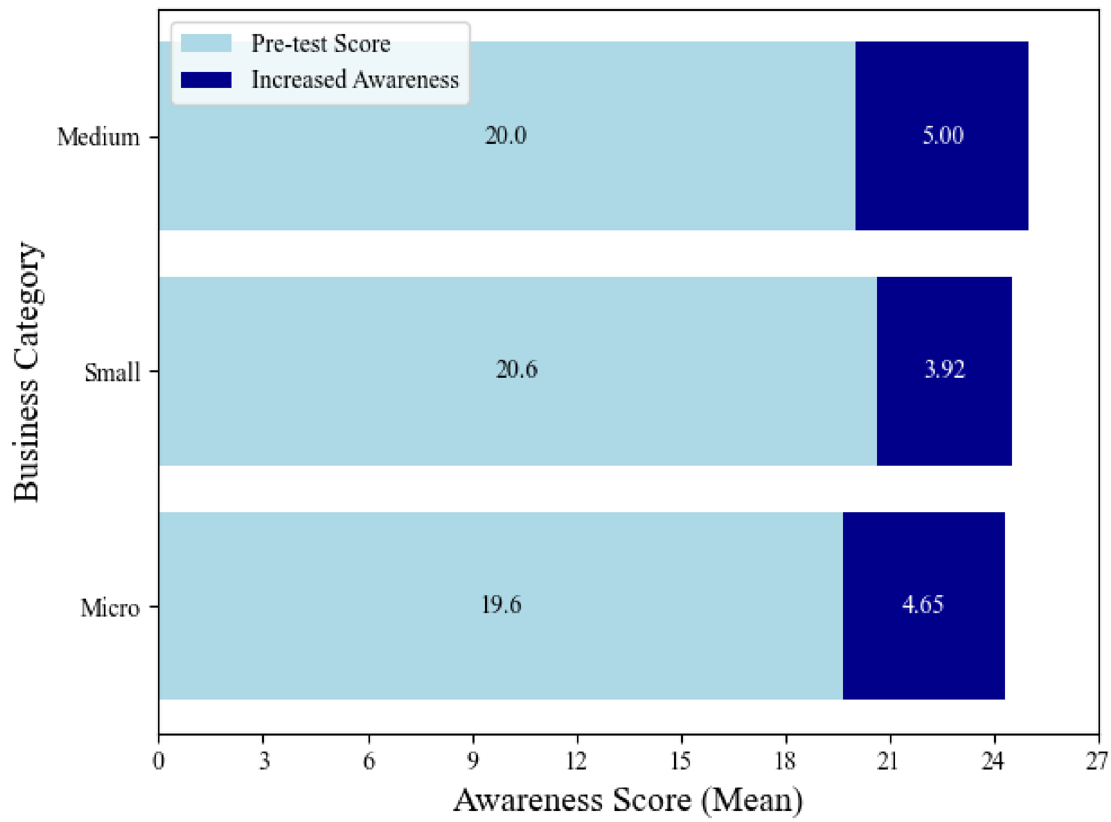

Figure 14. Increased Awareness per Business Category

This notable increase suggests that although medium businesses began with a similar baseline awareness to smaller businesses, they may have interacted more critically with the material, maybe due to more structured operations, higher energy consumption, or greater interest in cost-saving measures.

The overall findings show that the educational intervention had a good effect on all business sizes; medium businesses benefited most in terms of knowledge acquisition. These results show how well-focused, easily available educational materials raise awareness and imply that different approaches depending on company size and context should be considered in the next energy efficiency campaigns to maximize effect.

Opportunities to Improve Energy Efficiency

Figure 15 represents practices for enhancing energy efficiency applicable to MSMEs to improve energy efficiency.

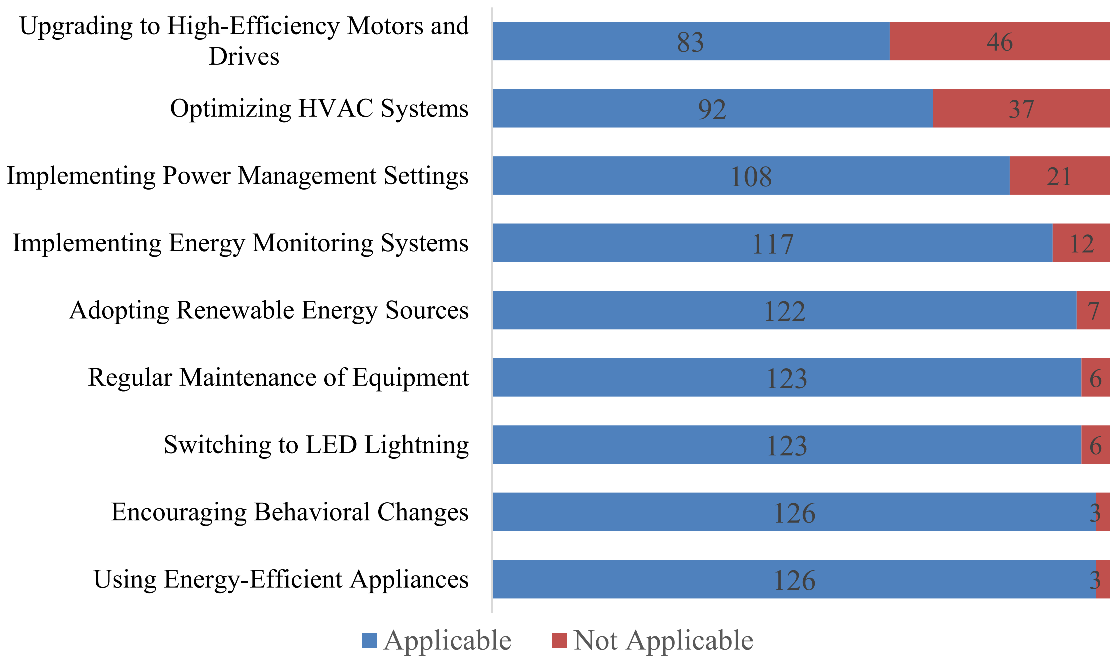

Figure 15. Opportunities to Improve Energy Efficiency.

Of the 129 respondents surveyed, various fundamental efficiency enhancement practices were identified as key opportunities for improving energy performance. Based on Figure 15, the top three most frequently identified opportunities across all MSME types were: (1) shifting to LED lighting systems, (2) regular maintenance and cleaning of equipment, and (3) unplugging unused devices or appliances. These practices were selected by more than 70% of the respondents, indicating high levels of awareness and practical alignment with day-to-day business needs.

Ninety-five percent of the respondents acknowledged the applicability of switching to LED lighting and conducting regular equipment maintenance, underscoring a broad awareness of the benefits associated with simple, cost-effective efficiency improvements. In a similar vein, the use of energy-efficient appliances and the promotion of behavioral changes received the highest level of agreement, with 126 respondents recognizing their relevance. The consensus reflects a significant readiness among MSMEs to implement straightforward and effective strategies for the immediate reduction of energy consumption.

One hundred twenty-two respondents indicated that the adoption of renewable energy sources, including solar photovoltaic systems, is a viable option, demonstrating an increasing interest in sustainable long-term solutions. Implementation of energy monitoring systems received endorsement from 117 respondents, indicating a clear recognition of the significance of tracking and managing energy consumption to enhance efficiency. The implementation of power management settings, such as automatic shutdowns and sleep modes, was relevant for 108 respondents, indicating a slightly lower yet significant level of acceptance, likely affected by the diversity of device types and system infrastructures across various industries.

The optimization of HVAC systems elicited a mixed response, with 92 respondents deeming it applicable and 37 indicating it was not applicable. This finding indicates that certain MSMEs either function in sectors with limited HVAC systems or have already optimized them, or they encounter barriers to investing in HVAC improvements. The adoption of high-efficiency motors and drives was perceived as having the lowest applicability, with only 83 respondents in agreement. The 46 respondents who considered it not applicable may represent businesses lacking significant motor-driven processes or those for whom the cost of retrofitting such equipment is prohibitively high compared to the anticipated savings.

With few "Not Applicable" responses noted, Table E1 (See Appendix E) shows that basic energy efficiency practices—such as switching to LED lighting, using energy-efficient appliances, and encouraging behavioral modifications—are generally relevant across many sectors. Though with some differences between the retail and manufacturing sectors, regular maintenance and energy monitoring systems are applicable to most MSMEs per industry type. On the other hand, advanced interventions like HVAC optimization and the switch to high-efficiency motors are not applicable to some MSMEs, particularly in retail where 29 respondents considered it not applicable for both practices. Though basic practices are generally accepted, the observed variations show that the application of more technical measures varies across sectors, probably influenced by operational, infrastructure, or resource-related elements.

Data indicate significant potential for enhancing energy efficiency via practical and implementable strategies, especially in the areas of lighting, appliance performance, equipment upkeep, and behavioral changes. Higher-investment strategies like HVAC optimization and motor upgrades, although not universally applicable, offer significant opportunities for specific sectors. The findings highlight that customized interventions, aligned with the operational realities of each MSME type, could enhance energy savings and facilitate the broader transition to more sustainable practices.

Furthermore, during informal discussions with selected participants, many expressed that they prioritize “what is immediately visible” (e.g., lighting, unplugging) over “invisible consumption” such as phantom loads or inefficiencies in motor operations. This suggests a need to strengthen technical education and awareness campaigns, especially those that can demonstrate the long-term savings of higher-impact interventions.

In terms of feasibility, the top three practices present excellent entry points for future energy conservation programs due to their ease of adoption. However, for broader and sustained impact, capacity-building interventions and possibly public-private support mechanisms are needed to help MSMEs transition toward more structured energy management systems.

Additional Energy Management Practices

Sixteen MSME participants provided qualitative observations on creative energy management strategies. The answers revealed a range of techniques meant to improve energy efficiency; nevertheless, many participants claimed to have used either few or none at all new ideas.

Many respondents said "none," or "none as of right now," implying that some MSMEs still have room for future growth in formal or advanced energy management systems. Several respondents have underlined the ongoing application of basic efficiency measures, including the choice of LED lighting in their buildings, which not only lowers running costs over time but also helps to cut electricity consumption.

Energy-efficient Machinery

Many companies have claimed using energy-efficient machinery; examples include juice extraction machines that now produce four liters per minute on the left side shown in Figure 15, an increase from the previous one liter per minute, greatly improving energy productivity.

Figure 16. Energy Efficient Machinery.

Acceptance of Solar Energy

Respondents reported using solar energy, suggesting that some have set up solar-generated equipment such as solar street lights and panels installed at the top of their cart shown in Figure 16, so drastically lowering their dependence on conventional grid power. Other creative ideas advanced more. A thorough overview of a sophisticated energy management system including smart building technologies for real-time energy monitoring and control revealed.

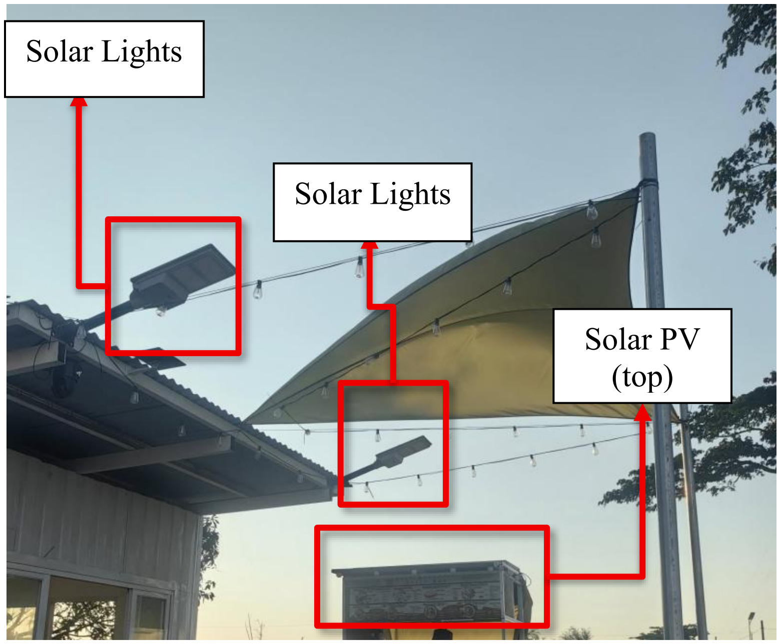

Figure 17. The Use of Solar Lights as Energy Alternatives and Solar PV Setup.

Energy Storage Systems

Systems for storing energy, including batteries, are used to improve energy availability during periods of maximum demand.

Energy management software

Data-driven energy optimization results from the monitoring of consumption patterns and areas for improvement identification made possible by energy management software.

Retro-commissioning

One of the respondents' practices said that retro-commissioning is the methodical review of system performance and equipment to preserve energy economy.

Use of Inverters and Car Batteries

Also notable is the use of inverters and car batteries. Several respondents said they used battery inverters and car batteries as substitute energy sources, showing small-scale but useful backup and storage solutions.

Method of behavior

One quick comment, "*iddepen no haan usaren*" turn off if not in use" in Ilocano — shows a basic strategy for behavioral modification: encouraging a culture of energy economy by means of the practice of turning off inactive machinery.

Many MSMEs are in the first stages of implementing creative energy strategies, showing development in basic efficiency practices including LED lighting and improved machine efficiency, as well as in more sophisticated systems including renewable energy, storage options, and smart management techniques. The collective activities show growing awareness of sustainable operations, suggesting great possibilities for the next energy-saving projects dependent on enough support and resource allocation.

Solar Photovoltaic (PV) System Recommendations

The study finally recommends a solar photovoltaic (PV) system based on the calculated setup. 118 out of 129 respondents may opt for a solar PV design setup as shown in Table 5. Based on the computed daily energy consumption from 118 respondents interested in a solar PV system, a customized solar PV recommendation was developed. Comprising 65 MSMEs most of them were advised for a 1 kWp solar PV system, implying that most have rather low daily energy consumption, which are suitable for

Table 5. Recommended solar photovoltaic (PV) setup.

Recommended PV Setup	**Male**	**Female**	**Total**
1 kWp	35	30	65
2 kWp	8	4	12
3 kWp	2	0	2
4 kWp	0	5	5
5 kWp	2	6	8
6 kWp	6	3	9
8 kWp	1	0	1
12 kWp	0	3	3
13 kWp	2	0	2
20 kWp	3	0	3
21 kWp	1	0	1
23 kWp	3	0	3
25 kWp	3	0	3
96 kWp	0	1	1

small-scale installations. Within the 2–6 kWp range, further clusters are found consisting of 12 respondents at 2 kWp, nine respondents at 6 kWp, and eight respondents at 5 kWp, indicating moderate consumption among a significant number of participants. This distribution shows how feasible it is to apply solar energy over several operational sizes.

A small number of respondents, especially those with more operational needs, were advised to consider systems ranging from 8 kWp to 96 kWp, highlighting the spectrum of corporate sizes and energy requirements across many different sectors. Every one of the 129 respondents showed reasonable solar PV sizing fit for their consumption pattern. Furthermore, a previous poll revealed that 121 of 129 respondents (94.57%) agreed that renewable energy would be relevant for their activities. This highlights MSME technical viability and solar adoption interest.

Table 6 was based on the computed daily energy consumption of MSMEs, the table shows advised solar PV configurations. The estimated system capacity in kilowatts (kWp), the number of 500W panels, inverter size, system voltage, and required battery storage in ampere-hours (Ah), make up the configuration. Since the real ground or roof area of every MSMEs was not collected in the study, the use of 500W panels sets a baseline for approximating the number of panels. Subject to variation depending on the number of panel strings and system configuration, inverter sizing shows an estimated need with a 20–25% buffer.

Capacity thresholds define system voltage recommendations, such 12V, 24V, or 48V; higher voltages used for larger systems help to improve safety and efficiency in current handling.

Table 6. Photovoltaic (PV) setup recommendation based on manual computation.

Recommended Setup	Solar Array (500W Panels)	Inverter Size (kWp)	System Voltage	Battery Sizing (Ah)	Recommended Battery Bank (Ah)	12V 100Ah Battery Units
1 kWp	2	1.20	12 V	83.33	100 Ah	1 unit
2 kWp	4	2.40	24 V	83.33	100 Ah	1 unit
3 kWp	6	3.60	48 V	62.50	100 Ah	1 unit
4 kWp	8	4.80	48 V	83.33	100 Ah	1 unit
5 kWp	10	6.00	48 V	104.17	150 Ah	2 units
6 kWp	12	7.20	48 V	125.00	150 Ah	2 units
8 kWp	16	9.60	48 V	166.67	200 Ah	2 units
12 kWp	24	14.40	48 V	250.00	250 Ah	3 units
13 kWp	26	15.60	48 V	270.83	300 Ah	3 units
20 kWp	40	24.00	48 V	416.67	450 Ah	5 units
21 kWp	42	25.20	48 V	437.50	450 Ah	5 units
23 kWp	46	27.60	48 V	479.17	500 Ah	5 units
25 kWp	50	30.00	48 V	520.83	550 Ah	6 units
96 kWp	192	115.20	48 V	2000.00	2000 Ah	20 units

Appropriate storage capacity for operations outside of daylight hours guarantees by battery sizing, so improving dependability and sustainability. Load patterns and discharge depth define actual performance and autonomy as well. Because of their great energy demand and impractical battery storage, systems exceeding 20 kWp are usually discouraged for standalone configurations; grid-tied or hybrid systems are more suited in these cases.

Estimated Savings from Proposed Systems

In order to maximize the reception of solar irradiance, the system parameters were set up to default settings to resemble a typical installation such as fixed roof-mounted array, standard module type, 20-degree tilt, and 180-degree azimuth. A DC to AC size ratio of 1.2, an inverter efficiency of 96%, and system losses of 14.08% were among the other technical requirements. The ground coverage ratio and bifacial settings were left at their default settings. The coordinates of Ilocos Norte (Latitude 18.21°, Longitude 120.58°) at an elevation of 10 meters were used in the location input. Irradiance losses per month were deemed insignificant, suggesting consistent and ideal solar availability throughout the year. The result was generated by PV Watts (See Appendices). To get the projected savings, AC output average per month was calculated and multiplied by the estimated cost per kWh, as shown in Table 7.

Assuming perfect solar conditions in Ilocos Norte, the PVWatts simulation results provided a structured estimate of monthly energy output and related financial savings for every recommended PV system size.

Table 7. Monthly and annual projected savings from using solar PV system.

Recommended PV Setup	Mean Monthly AC Output (kWh)	Projected Monthly Savings	Projected Annual Savings
1 kWp	129.70	PHP 1,426.70	PHP 17,120.44
2 kWp	259.40	PHP 2,853.41	PHP 34,240.88
3 kWp	389.10	PHP 4,280.11	PHP 51,361.33
4 kWp	518.80	PHP 5,706.81	PHP 68,481.78
5 kWp	648.50	PHP 7,133.52	PHP 85,602.21
6 kWp	778.20	PHP 8,560.22	PHP 102,722.63
8 kWp	1037.60	PHP 11,413.63	PHP 136,963.52
12 kWp	1556.40	PHP 17,120.44	PHP 205,445.28
13 kWp	1686.10	PHP 18,547.14	PHP 222,565.74
20 kWp	2594.01	PHP 28,534.07	PHP 342,408.83
21 kWp	2723.71	PHP 29,960.77	PHP 359,529.27
23 kWp	2983.11	PHP 32,814.18	PHP 393,770.14
25 kWp	3242.51	PHP 35,667.59	PHP 428,011.05
96 kWp	12451.23	PHP 136,963.53	PHP 1,643,562.34

The dependability of capacity-based scaling in PV system design was confirmed by the consistency and proportional increase in energy generated shown by the outputs with system size. Predicted savings grew gradually throughout system sizes as each kilowatt-hour installed solar capacity generated almost 130 kWh of AC power monthly. These projections, based on fixed assumptions including a 1.2 DC-to-AC size ratio, 14.08% system losses, and ideal panel orientation, reflected real-world installation guidelines.

While the expected values show the theoretical maximum under ideal conditions, real-world factors including shading, equipment degradation, weather variation, and load mismatches may affect actual system performance. Still, some degree of inefficiencies is allowed by design buffers including cautious loss estimations and small oversizing.

According to the study, many systems will also periodically generate extra energy beyond their current need. Applying net metering or integration of hybrid storage systems was advised to maximize the financial benefit of such surplus. These systems would let MSMEs offset energy costs at night or during low output, improving the long-term return on investment of the PV systems and so supporting energy sustainability for small businesses. After the solar PV system is installed, MSME operators ought to preserve their present energy-saving strategies. This assumption is essential to guarantee that the financial and environmental advantages of the system are totally realized since consistent energy-conscious actions will reduce running expenses and stop unnecessary system overloads or inefficiencies.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This chapter presents the summary of findings, conclusion and recommendations of the study.

Summary

This study investigated the energy usage profiles and efficiency enhancement potential of selected MSMEs in Ilocos Norte, drawing from both field data and existing literature. Owners, managers, and technical staff, who are accountable for daily operations and energy consumption, participated in the study. A mixed-methods approach was utilized, combining a standardized survey with an informational brochure to gather data on energy consumption, efficiency practices, and awareness. Surveys were administered before and after the awareness intervention, and the responses were analyzed through descriptive statistics and a paired t-test to evaluate changes in awareness. Personalized solar PV system recommendations were developed and simulated using PVsyst and PVWatts tools, based on reported energy use, with parameters tailored to the solar conditions of Ilocos Norte. System configurations were assessed for both technical and economic viability, with anticipated monthly cost savings determined based on an assumed electricity rate.

Findings

Supported by related research, which emphasizes the impact of awareness campaigns and data-driven interventions on energy behavior, the findings showed that most MSMEs operate with low energy intensity, particularly micro-enterprises that made up the bulk of the respondents. Through equipment-level energy audits, the study identified refrigeration, lighting, and ventilation as the top energy-consuming categories, aligning with prior studies that highlight these as key drivers of electricity use in small enterprises.

The results showed that most MSMEs operate within a low energy intensity range, with cooling, lighting, and refrigeration being the most energy-demanding processes. Though most MSMEs fall in the lowest energy-intensity range, targeted efficiency measures are required for a few outliers across several industries. The daily consumption shows operational and demand cycles; it peaks on Friday and falls on Sundays. Moreover, the weak correlation between running hours and energy consumption implies that general consumption is driven by equipment type and usage patterns instead of runtime by itself.

Through a structured awareness intervention, the study also revealed increased understanding and adoption of energy-efficient practices, particularly in relation to renewable energy. Post-awareness assessments revealed a marked improvement in renewable energy understanding, specifically on adopting renewable energy sources, which increased by 1.02 points from pre- to post-test scores.

The assessment of energy efficiency practices highlighted strong applicability in areas such as LED lighting, behavioral changes, and energy-efficient appliances, presenting immediate opportunities for improvement.

Based on the consumption profiles, solar PV system layouts were recommended as long-term solutions, particularly for businesses with stable daily demand. These recommendations, supported by battery storage sizing and system voltage configurations, aim to promote sustainability and competitiveness.

Based on their calculated daily energy consumption, tailored solar PV setups were recommended, with most businesses falling within the 1 to 6 kWp system range. The computations included estimations for inverter size, system voltage, and battery capacity, though higher-capacity systems (above 20 kWp) were not encouraged to pursue standalone setups due to cost and storage limitations. Battery storage remains essential for off-grid reliability but is economically viable primarily for small to mid-sized installations. Single line diagram grid tie setup is provided as recommendation.

Conclusions

The current energy consumption of MSMEs in Ilocos Norte was assessed through equipment-level profiling, establishing a baseline for daily kWh usage and intensity. This baseline, while subject to refinement as additional data becomes available, is anticipated to decrease with increased awareness. Distinct consumption patterns were observed; however, certain patterns require enhancement through energy-efficient practices. An educational brochure effectively increased the awareness of context-specific practices among owners and managers; however, the applicability of each recommendation is dependent on the equipment portfolio of individual MSMEs. To achieve carbon-reduction objectives while maintaining operational efficiency, the foremost best practice involves the implementation of solar photovoltaic systems, preferably under net-metering agreements to enhance surplus generation and reduce costs.

In fact, adoption of renewable energy sources has shown great value in several real-world examples from the Philippines across different MSME industries. Solar projects have let cooperatives in agriculture restore production capacity, lower costs, and raise product value. Similarly, while urban cold storage facilities and hotels have used solar power to lower utility costs and support sustainable branding, off-grid retail stores have used solar microgrids to extend business hours and serve community needs.

Collectively, these examples highlight the adaptability and scalability of solar energy, traits that fit very nicely with the several running needs of MSMEs. Driven by these revelations, the study created tailored PV system recommendations based on real-world energy consumption profiles, so ensuring that the size, inverter capacity, voltage, and battery storage of every system matched particular business needs.

Consequently, these suggestions aimed in two different directions: they gave MSMEs informed choices for lowering energy reliance and costs, and they validated the viability of solar adoption using operating data. Under ideal conditions, simulated monthly outputs and cost savings produced by the PVWatts calculator underlined the financial promise of the suggested systems.

However, although the expected performance was ideal, the inclusion of design buffers explained normal system losses, so ensuring that recommendations stayed sensible. Encouragingly, systems generating energy beyond immediate use could benefit from net metering or hybrid configurations, so maximizing return on investment and supporting sustainable energy management for MSMEs.

Recommendations

To support adoption, MSMEs are encouraged to take advantage of accessible financing models or the Government Energy Option Program. Across the Philippines, various solar companies and government-supported programs offer solar PV systems on installment, lease-to-own, or pay-as-you-go arrangements, making solar more attainable for small enterprises. These are often bundled with promotional offers, after-sales service, and government incentives such as tax credits or low-interest green loans. With appropriate support and planning, MSMEs in Ilocos Norte can transition toward a more efficient and sustainable energy model, in line with national goals for renewable energy development.

Follow-up research may evaluate the persistence of behavioral changes following interventions. Additionally, comprehensive life-cycle cost–benefit analyses of solar PV and net-metering across diverse MSME profiles, along with an examination of supportive policy and financing frameworks, will elucidate strategies for widespread and sustained adoption of renewable energy.

This paper focused on solar photovoltaic (PV) systems as the main renewable energy source for MSMEs; future projects should investigate other renewable energy technologies that might be more appropriate for specific geographical areas. Particularly in towns like Bangui, Burgos, and Pagudpud, which are known for their great wind resources and established utility-scale wind farms, wind energy shows great potential for localized implementation in the northern coastal areas of Ilocos Norte.

Small-scale wind energy systems could benefit MSMEs located in or near these high-wind potential sites either as independent sources or as hybrid systems coupled with solar photovoltaic technology.

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APPENDICES

APPENDIX A

EXEMPT RESEARCH CERTIFICATE

MARIANO MARCOS STATE UNIVERSITY
University Research Ethics Review Board

BAGONG PILIPINAS

EXEMPT RESEARCH CERTIFICATE

Reference Number: **2024-454**

Research Title: **ENERGY PROFILING AND EFFICIENCY ENHANCEMENT OF SELECTED MICRO-SMALL-MEDIUM ENTERPRISE IN ILOCOS NORTE**

Nature of Research: **MASTER'S THESIS**

Lead Researcher: **JOMEL FELIX**

On behalf of the University Research Ethics Review Board (URERB), I hereby certify that the above-mentioned research project is qualified as exempt research under the category/ies:

"4. Research involving the collection or study of existing data, documents, records, pathological specimen, or diagnostic specimen"

The researcher(s) may therefore commence with the research as from the date of this certificate, using the reference number indicated above.

Please note that the certification is effective **September 27, 2024 to September 27, 2025.** Likewise, post-approval submissions are not necessary; however, all modifications to the study that has been certified as exempt research must be submitted to the board for prospective review and certification of exemption prior to implementation.

CERTIFIED TRUE AND CORRECT:

MARILOU J. RAVAL
Secretary

RHIAN JAYMAR D. RAMIL
Chair

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APPENDIX B

CHECKLIST AND SURVEY QUESTIONS

PROFESSIONAL SCIENCE MASTERS IN RENEWABLE ENERGY ENGINEERING
CAPSTONE PROJECT
CHECKLIST AND GUIDE QUESTIONS

BACKGROUND

Dear Respondents:

Micro, Small, and Medium-Sized Enterprises (MSMEs) are key drivers of economic growth in Ilocos Norte, Philippines, but they face significant challenges due to rising energy costs and inefficient energy consumption. These issues impact their profitability, sustainability, and overall competitiveness. Despite available energy-saving measures and initiatives by the Department of Energy (DOE), many MSMEs lack the necessary data and awareness to effectively implement energy-efficient practices.

This study aims to fill these gaps by analyzing energy consumption patterns within MSMEs in Ilocos Norte using a combination of surveys, on-site energy audits, document analysis, and benchmarking. In connection to this, the present capstone envisions to provide a plan or blueprint, leaving the decision to adopt and implement these recommendations entirely up to the MSME owners.

JOMEL C. FELIX
Researcher

Directions:
The goal this capstone project is to gather energy consumption profiling and pre and post interview survey, identify opportunities for improvement, and develop tailored recommendations to enhance energy efficiency. By doing so, the study seeks to improve the sustainability and competitiveness of MSMEs in the region. Your responses will help identify opportunities for energy-saving measures and evaluate the impact of awareness campaigns on improving energy efficiency.

Thank you for participating in this survey. All responses will be kept confidential and will be used only for research purposes.

Consent:

I have read and understood the above information and had been given the opportunity to consider and ask questions on the information regarding the involvement in this study. I have received a copy of this informed consent document. (URERB-FRM-009)

__________________ Participant's Name　　________________ Signature　　_______________ Date Signed

Part 1: Socio-cultural demographics/Professional Background

Name (Optional)	Age:	Sex:
Business Name:		
Business Address:		
Industry Type: ○ Manufacturing ○ Retail ○ Services ○ Agriculture ○ Others (please specify)	Business Operations: ________________	Business Category: ○ Micro (₱3,000,000 or less) ○ Small (₱3,000,001 to ₱15,000,000) ○ Medium (₱15,000,001 to ₱100,000,000)

Part 2. Energy Profiling

2.1 Energy Profiling based on electricity bill for the last 3 months

What was your electricity consumption (in KW) for the most recent month?" (Example: February 2025)	What was your electricity consumption (in KW) for the second most recent month?" (Example: January 2025)	What was your electricity consumption (in kWh) for the third most recent month?" (Example: December 2024)
○ Less than 100KW ○ 100-300KW ○ 301-500KW ○ 500-1000KW ○ More than 1000KW	○ Less than 100KW ○ 100-300KW ○ 301-500KW ○ 500-1000KW ○ More than 1000KW	○ Less than 100KW ○ 100-300KW ○ 301-500KW ○ 500-1000KW ○ More than 1000KW

2.2 Energy consumption by equipment

	Number of units/equipments	Number of hours used per day	Total estimated power rating
Lighting & Electrical Fixtures (LED Bulbs, Fluorescent Lamps, Emergency Lights, Outdoor Signage, Neon Lights)	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ More than 4	○ 0 ○ Less than 1 hr ○ 1-2 hrs ○ 3-4 hrs ○ 5-8 hrs ○ More than 8 hrs	○ 0 ○ Less than 50W ○ 51-200W ○ 201-500W ○ 501-1000W ○ More than 1000W
Cooling & Ventilation (Electric Fans, Air Conditioners, Exhaust Fans, Air Purifiers, Dehumidifiers)	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ More than 4	○ 0 ○ Less than 1 hr ○ 1-2 hrs ○ 3-4 hrs ○ 5-8 hrs ○ More than 8 hrs	○ 0 ○ Less than 50W ○ 51-200W ○ 201-500W ○ 501-1000W ○ More than 1000W
Office & IT Equipment (Computers, Monitors, Printers, Scanners, Photocopiers, Routers, Modems, Cash Registers, POS Machines, Televisions, Projectors)	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ More than 4	○ 0 ○ Less than 1 hr ○ 1-2 hrs ○ 3-4 hrs ○ 5-8 hrs ○ More than 8 hrs	○ 0 ○ Less than 50W ○ 51-200W ○ 201-500W ○ 501-1000W ○ More than 1000W
Kitchen Equipment (Rice Cookers, Electric Stoves, Induction Cookers, Microwaves, Ovens, Toasters, Coffee Makers, Blenders, Food Warmers, Juicers)	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ More than 4	○ 0 ○ Less than 1 hr ○ 1-2 hrs ○ 3-4 hrs ○ 5-8 hrs ○ More than 8 hrs	○ 0 ○ Less than 50W ○ 51-200W ○ 201-500W ○ 501-1000W ○ More than 1000W
Refrigeration & Storage (Refrigerators, Freezers, Water Dispensers)	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ More than 4	○ 0 ○ Less than 1 hr ○ 1-2 hrs ○ 3-4 hrs ○ 5-8 hrs ○ More than 8 hrs	○ 0 ○ Less than 50W ○ 51-200W ○ 201-500W ○ 501-1000W ○ More than 1000W
Entertainment & Audio Equipment (Speakers, Amplifiers, Microphones, LED Display Panels, CCTV Systems)	○ 0 ○ 1 ○ 2 ○ 3	○ 0 ○ Less than 1 hr ○ 1-2 hrs ○ 3-4 hrs	○ 0 ○ Less than 50W ○ 51-200W ○ 201-500W

	○ 4 ○ More than 4	○ 5-8 hrs ○ More than 8 hrs	○ 501-1000W ○ More than 1000W
Industrial & Manufacturing Equipment (Electric Drills, Grinders, Welding Machines, Compressors, Conveyor Belts, Vacuum Sealers, Industrial Mixers)	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ More than 4	○ 0 ○ Less than 1 hr ○ 1-2 hrs ○ 3-4 hrs ○ 5-8 hrs More than 8 hrs	○ 0 ○ Less than 50W ○ 51-200W ○ 201-500W ○ 501-1000W ○ More than 1000W
Other Electrical Appliances (Not mentioned)	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ More than 4	○ 0 ○ Less than 1 hr ○ 1-2 hrs ○ 3-4 hrs ○ 5-8 hrs ○ More than 8 hrs	○ 0 ○ Less than 50W ○ 51-200W ○ 201-500W ○ 501-1000W ○ More than 1000W

Part 3. Awareness in Energy Efficiency and Conservation

3.1 Understanding the awareness of different programs, republic act and tips for energy efficiency and conservation. Choose only one answer.

Particulars	**Not at all Familiar**	**Slightly Familiar**	**Moderately Familiar**	**Extremely Familiar**
Republic Act No. 11285: An Act Institutionalizing Energy Efficiency And Conservation, Enhancing The Efficient Use Of Energy, And Granting Incentives To Energy Efficiency And Conservation Projects				
Promotion of Green Economic Development (Department of Trade and Industry)				
Household Energy Conservation Tips				

3.2 Pre-survey on Energy Efficiency Practices. Choose only one answer

Particulars			
Are you aware of the benefits of switching to LED lighting?	○ Yes, very aware	○ Somewhat aware	○ Not aware
Do you currently use power management settings on your computers and electronic devices?	○ Yes, always	○ Sometimes	○ No, never
How often do you perform maintenance on your business equipment to ensure energy efficiency?	○ Regularly	○ Occasionally	○ Rarely or never
Do you choose energy-efficient appliances when purchasing new equipment?	○ Yes, always	○ Sometimes	○ No, never
Are you aware of the benefits of optimizing your HVAC systems for energy efficiency?	○ Yes, very aware	○ Somewhat aware	○ Not aware
Do you use any renewable energy sources, such as solar panels?	○ Yes, currently using	○ Planning to use	○ No, not using
Do you monitor your energy usage regularly?	○ Yes, very aware	○ Somewhat aware	○ Not aware
Do you encourage energy-saving practices among your employees?	○ Yes, strongly encourage	○ Sometimes encourage	○ No, not encouraged
Are you aware with the benefits of upgrading to high-efficiency motors and drives?	○ Yes, very aware	○ Somewhat aware	○ Not aware

3.3. Understanding the Basic Energy Efficiency Practices

Particulars	Applicable	Not Applicable
Switching to LED Lighting: • Replacing traditional incandescent or fluorescent lights with energy-efficient LED bulbs to reduce electricity consumption		
Implementing Power Management Settings: • Using power management features on computers and other electronic devices to automatically reduce energy use when not in active use.		
Regular Maintenance of Equipment: • Performing routine maintenance on machines and equipment to ensure they are operating efficiently and not wasting energy.		
Using Energy-Efficient Appliances: • Choosing appliances and machinery with higher energy efficiency ratings, such as ENERGY STAR-certified products.		
Optimizing HVAC Systems: • Regularly servicing heating, ventilation, and air conditioning (HVAC) systems, and using programmable thermostats to control temperatures more effectively.		
Adopting Renewable Energy Sources: • Incorporating renewable energy sources, such as installing solar panels, to generate electricity and reduce reliance on grid energy.		
Implementing Energy Monitoring Systems: • Using energy monitoring tools to track energy usage in real-time and identify areas where energy is being wasted.		
Encouraging Behavioral Changes: • Promoting energy-saving behaviors among employees, such as turning off lights and equipment when not in use.		
Upgrading to High-Efficiency Motors and Drives: • Replacing old motors and drives with high-efficiency models to reduce energy consumption in industrial processes.		

3.4. Post-survey on Energy Efficiency Practices

Particulars	Yes	No
Have you considered switching to LED lighting after learning about its benefits?		
Did you start using power management settings on your computers and devices?		
Has your frequency of performing equipment maintenance for energy efficiency increased?		
Will you prioritize energy-efficient appliances when purchasing new equipment?		
Have you optimized your HVAC systems for better energy efficiency?		
Have you considered or started using renewable energy sources, such as solar panels?		
Are you now regularly monitoring your energy usage?		
Have you implemented more energy-saving practices among your employees?		
Have you considered upgrading to high-efficiency motors and drives after learning about their benefits?		

Part 4. Understanding innovative best practices in energy efficiency
Are there any innovative approaches to energy management that your business has adopted? If so, please describe them.

____
____
____

Part 5. Applying alternative energy efficiency and conservation such as renewable energy
Would you consider adopting a provided blueprint for a renewable energy setup, such as solar PV, as an alternative for improving your business's energy efficiency and conservation efforts?

○ Yes ○ No

Thank you for your participation!

APPENDIX C

CURRENT NUMBER OF MICRO, SMALL MEDIUM ENTERPRISES IN ILOCOS NORTE

Republic of the Philippines
PROVINCE OF ILOCOS NORTE

MICRO, SMALL, AND MEDIUM ENTERPRISE OFFICE

March 13, 2025

Mr. Jomel Felix
Instructor I
Mariano Marcos State University

Dear Mr. Felix,

Respectfully forwarding the requested data on the current number of **Micro, Small, and Medium Enterprises (MSMEs) in Ilocos Norte**, categorized by business size, for your capstone study titled *"Energy Profiling and Efficiency Enhancement of Selected MSMEs in Ilocos Norte."*

Please be assured that the provided data will be used solely for the said study and we look forward to its successful completion.

ILOCOS NORTE MICRO, SMALL, AND MEDIUM ENTERPRISES AS OF JANUARY 2024	
CLASSIFICATION	NUMBER OF MSMEs
Micro	21735
Small	517
Medium	178
Large	60
TOTAL	22490

Should you require any further information, please feel free to reach out.

Sincerely,

ELMA C. GABRIEL
Head

Ilocos Norte Provincial Capitol, Brgy.10, JP Rizal Street, Laoag City
Tel. (077)772-1212 loc. 125
Email: sme.pgin@gmail.com
Facebook: Provincial Small and Medium Enterprise Office - SMEO
Ilocos Norte MSME Incubation Center

APPENDIX D

ENERGY INTENSITY

Table D1. Energy intensity per business category.

Business Category	**Lowest** (< 20 kWh)	**Moderate** (20–39.99 kWh)	**High** (40–59.99 kWh)	**Highest** (60 kWh and above)
Micro	99	8	4	2
Small	11	1	1	0
Medium	2	0	1	0

APPENDIX E

OPPORTUNITIES TO IMPROVE ENERGY EFFICIENCY

Table E1. Opportunities to improve energy efficiency per industry type.

Basic Efficiency Enhancement Practices	Agriculture		Food and beverages		Manufacturing		Retail		Services	
	Appli cable	Not Appli cable	Appli cable	Not Appli cable	Applic able	Not Appli cable	Appli cable	Not Appli cable	Appli cable	Not Appli cable
Adopting Renewable Energy Sources	3	0	40	1	10	0	46	6	23	0
Encouraging Behavioral Changes	3	0	41	0	10	0	49	3	23	0
Implementing Energy Monitoring Systems	3	0	36	5	10	0	46	6	22	1
Implementing Power Management Settings	3	0	38	3	7	3	38	14	22	1
Optimizing HVAC Systems	0	3	37	4	9	1	23	29	23	0
Regular Maintenance of Equipment	3	0	41	0	10	0	46	6	23	0
Switching to LED Lightning	3	0	41	0	7	3	49	3	23	0
Upgrading to High-Efficiency Motors and Drives	3	0	30	11	10	0	23	29	17	6
Using Energy-Efficient Appliances	3	0	41	0	10	0	49	3	23	0

APPENDIX F

SINGLE LINE DIAGRAM OF RECOMMENDED PV SETUPS

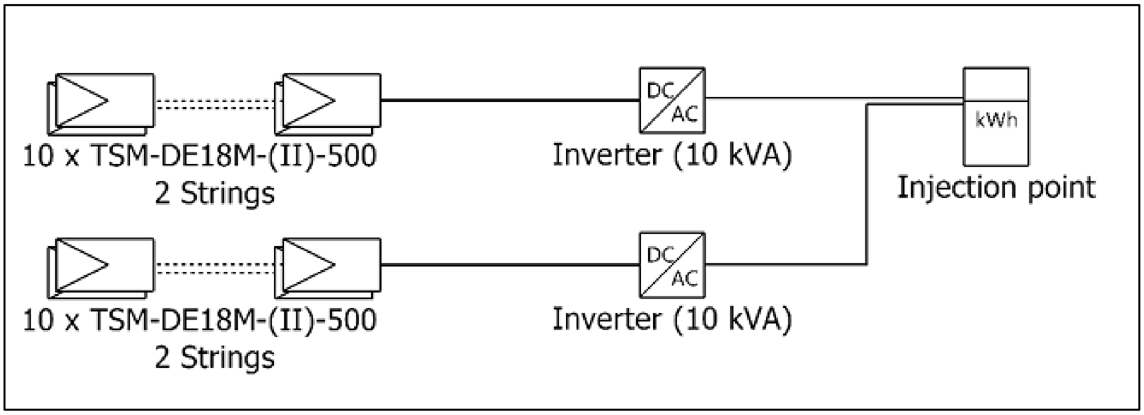

Figure F1. Single Line Diagram of 20 kWp Setup.

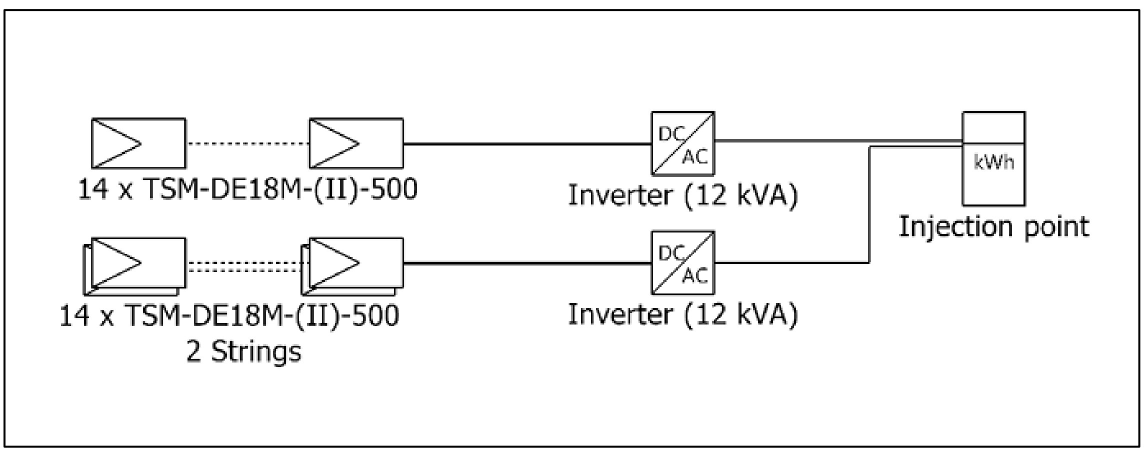

Figure F2. Single Line Diagram of 21 kWp Setup.

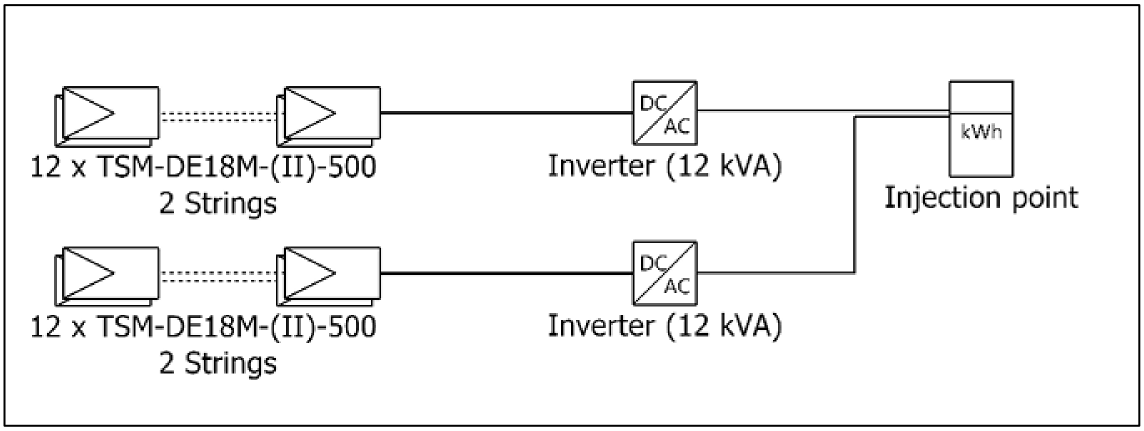

Figure F3. Single Line Diagram of 23 kWp PV Setup.

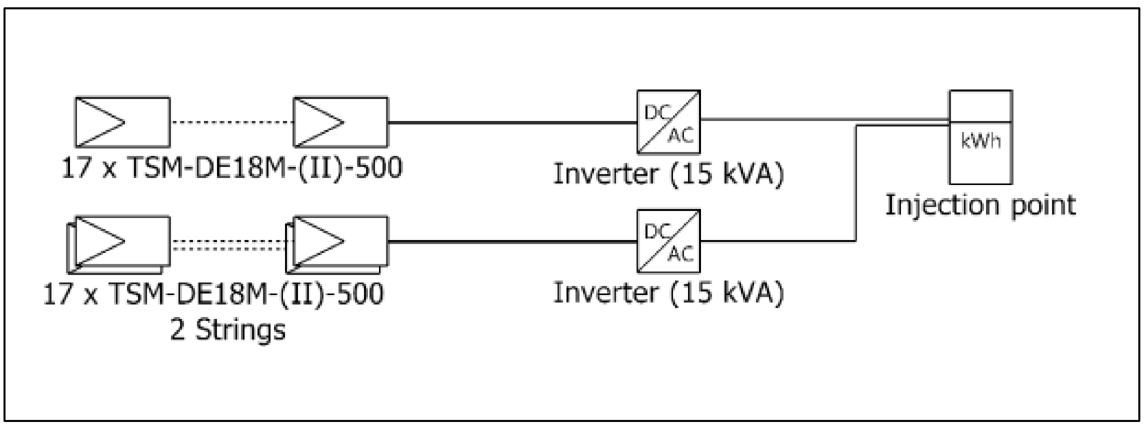

Figure F4. Single Line Diagram of 25 kWp PV Setup.

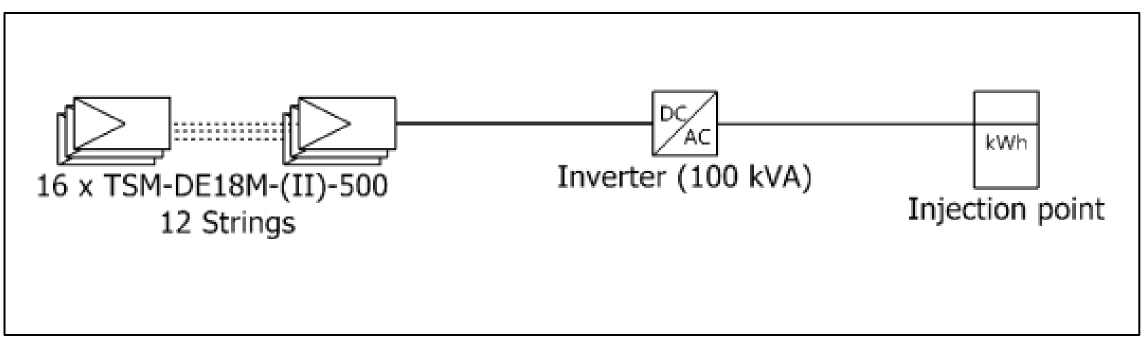

Figure F5. Single Line Diagram of 96 kWp PV Setup.

APPENDIX G

PVWATTS CALCULATION RESULTS

NREL

Caution: Photovoltaic system performance predictions calculated by PVWatts® include many inherent assumptions and uncertainties and do not reflect variations between PV technologies nor site-specific characteristics except as represented by PVWatts® inputs. For example, PV modules with better performance are not differentiated within PVWatts® from lesser performing modules. Both NREL and private companies provide more sophisticated PV modeling tools (such as the System Advisor Model at //sam.nrel.gov) that allow for more precise and complex modeling of PV systems.

The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

Disclaimer: The PVWatts® Model ("Model") is provided by the National Renewable Energy Laboratory ("NREL"), which is operated by the Alliance for Sustainable Energy, LLC ("Alliance") for the U.S. Department Of Energy ("DOE") and may be used for any purpose whatsoever.

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The energy output range is based on analysis of 30 years of historical weather data, and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

1,556 kWh/Year*

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	6.18	145
February	6.82	143
March	7.18	163
April	7.03	153
May	5.91	133
June	5.49	119
July	4.97	111
August	4.35	99
September	5.56	121
October	5.59	129
November	4.85	111
December	5.49	130
Annual	**5.79**	**1,557**

Location and Station Identification

Requested Location	ilocos norte
Weather Data Source	Lat, Lng: 18.21, 120.58 1.3 mi
Latitude	18.21° N
Longitude	120.58° E

PV System Specifications

DC System Size	1 kW
Module Type	Standard
Array Type	Fixed (roof mount)
System Losses	14.08%
Array Tilt	20°
Array Azimuth	180°
DC to AC Size Ratio	1.2
Inverter Efficiency	96%
Ground Coverage Ratio	0.4
Albedo	*From weather file*
Bifacial	No (0)

Monthly Irradiance Loss

Jan	Feb	Mar	Apr	May	June
0%	0%	0%	0%	0%	0%

July	Aug	Sept	Oct	Nov	Dec
0%	0%	0%	0%	0%	0%

Performance Metrics

DC Capacity Factor	17.8%

Figure G1. PVWatts Calculation Results for 1 kWp PV Setup.

NREL

NATIONAL RENEWABLE ENERGY LABORATORY

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The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

The energy output range is based on analysis of 30 years of historical weather data, and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

3,113 kWh/Year*

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	6.18	291
February	6.82	286
March	7.18	326
April	7.03	306
May	5.91	265
June	5.49	238
July	4.97	222
August	4.35	199
September	5.56	242
October	5.59	257
November	4.85	222
December	5.49	261
Annual	**5.79**	**3,115**

Location and Station Identification

Requested Location	ilocos norte
Weather Data Source	Lat, Lng: 18.21, 120.58 1.3 mi
Latitude	18.21° N
Longitude	120.58° E

PV System Specifications

DC System Size	2 kW
Module Type	Standard
Array Type	Fixed (roof mount)
System Losses	14.08%
Array Tilt	20°
Array Azimuth	180°
DC to AC Size Ratio	1.2
Inverter Efficiency	96%
Ground Coverage Ratio	0.4
Albedo	*From weather file*
Bifacial	No (0)

Monthly Irradiance Loss

Jan	Feb	Mar	Apr	May	June
0%	0%	0%	0%	0%	0%
July	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
0%	0%	0%	0%	0%	0%

Performance Metrics

DC Capacity Factor	17.8%

Figure G2. PVWatts Calculation Results for 2 kWp PV Setup.

NREL

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The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

The energy output range is based on analysis of 30 years of historical weather data, and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

4,669 kWh/Year*

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	6.18	436
February	6.82	429
March	7.18	489
April	7.03	459
May	5.91	398
June	5.49	357
July	4.97	332
August	4.35	298
September	5.56	363
October	5.59	386
November	4.85	332
December	5.49	391
Annual	5.79	4,670

Location and Station Identification

Requested Location	ilocos norte
Weather Data Source	Lat, Lng: 18.21, 120.58 1.3 mi
Latitude	18.21° N
Longitude	120.58° E

PV System Specifications

DC System Size	3 kW
Module Type	Standard
Array Type	Fixed (roof mount)
System Losses	14.08%
Array Tilt	20°
Array Azimuth	180°
DC to AC Size Ratio	1.2
Inverter Efficiency	96%
Ground Coverage Ratio	0.4
Albedo	*From weather file*
Bifacial	No (0)

Monthly Irradiance Loss

Jan	Feb	Mar	Apr	May	June
0%	0%	0%	0%	0%	0%
July	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
0%	0%	0%	0%	0%	0%

Performance Metrics

DC Capacity Factor	17.8%

Figure G3. PVWatts Calculation Results for 3 kWp PV Setup.

NREL

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The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

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The energy output range is based on analysis of 30 years of historical weather data, and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

6,226 kWh/Year*

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	6.18	582
February	6.82	572
March	7.18	651
April	7.03	612
May	5.91	530
June	5.49	476
July	4.97	443
August	4.35	397
September	5.56	483
October	5.59	514
November	4.85	443
December	5.49	521
Annual	**5.79**	**6,224**

Location and Station Identification

Requested Location	ilocos norte
Weather Data Source	Lat, Lng: 18.21, 120.58 1.3 mi
Latitude	18.21° N
Longitude	120.58° E

PV System Specifications

DC System Size	4 kW
Module Type	Standard
Array Type	Fixed (roof mount)
System Losses	14.08%
Array Tilt	20°
Array Azimuth	180°
DC to AC Size Ratio	1.2
Inverter Efficiency	96%
Ground Coverage Ratio	0.4
Albedo	*From weather file*
Bifacial	No (0)

Monthly Irradiance Loss

Jan	Feb	Mar	Apr	May	June
0%	0%	0%	0%	0%	0%

July	Aug	Sept	Oct	Nov	Dec
0%	0%	0%	0%	0%	0%

Performance Metrics

DC Capacity Factor	17.8%

Figure G4. PVWatts Calculation Results for 4 kWp PV Setup.

NREL

NATIONAL RENEWABLE ENERGY LABORATORY

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The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

The energy output range is based on analysis of 30 years of historical weather data, and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

7,782 kWh/Year*

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	6.18	727
February	6.82	715
March	7.18	814
April	7.03	764
May	5.91	663
June	5.49	595
July	4.97	554
August	4.35	497
September	5.56	604
October	5.59	643
November	4.85	554
December	5.49	652
Annual	**5.79**	**7,782**

Location and Station Identification

Requested Location	ilocos norte
Weather Data Source	Lat, Lng: 18.21, 120.58 1.3 mi
Latitude	18.21° N
Longitude	120.58° E

PV System Specifications

DC System Size	5 kW
Module Type	Standard
Array Type	Fixed (roof mount)
System Losses	14.08%
Array Tilt	20°
Array Azimuth	180°
DC to AC Size Ratio	1.2
Inverter Efficiency	96%
Ground Coverage Ratio	0.4
Albedo	*From weather file*
Bifacial	No (0)

Monthly Irradiance Loss

Jan	Feb	Mar	Apr	May	June
0%	0%	0%	0%	0%	0%

July	Aug	Sept	Oct	Nov	Dec
0%	0%	0%	0%	0%	0%

Performance Metrics

DC Capacity Factor	17.8%

Figure G5. PVWatts Calculation Results for 5 kWp PV Setup.

NREL

Caution: Photovoltaic system performance predictions calculated by PVWatts® include many inherent assumptions and uncertainties and do not reflect variations between PV technologies nor site-specific characteristics except as represented by PVWatts® inputs. For example, PV modules with better performance are not differentiated within PVWatts® from lesser performing modules. Both NREL and private companies provide more sophisticated PV modeling tools (such as the System Advisor Model at //sam.nrel.gov) that allow for more precise and complex modeling of PV systems.

The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

The energy output range is based on analysis of 30 years of historical weather data, and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

9,338 kWh/Year*

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	6.18	873
February	6.82	858
March	7.18	977
April	7.03	917
May	5.91	795
June	5.49	714
July	4.97	665
August	4.35	596
September	5.56	725
October	5.59	772
November	4.85	665
December	5.49	782
Annual	**5.79**	**9,339**

Location and Station Identification

Requested Location	ilocos norte
Weather Data Source	Lat, Lng: 18.21, 120.58 1.3 mi
Latitude	18.21° N
Longitude	120.58° E

PV System Specifications

DC System Size	6 kW
Module Type	Standard
Array Type	Fixed (roof mount)
System Losses	14.08%
Array Tilt	20°
Array Azimuth	180°
DC to AC Size Ratio	1.2
Inverter Efficiency	96%
Ground Coverage Ratio	0.4
Albedo	*From weather file*
Bifacial	No (0)

Monthly Irradiance Loss

Jan	Feb	Mar	Apr	May	June
0%	0%	0%	0%	0%	0%

July	Aug	Sept	Oct	Nov	Dec
0%	0%	0%	0%	0%	0%

Performance Metrics

DC Capacity Factor	17.8%

Figure G6. PVWatts Calculation Results for 6 kWp PV Setup.

NREL

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The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

The energy output range is based on analysis of 30 years of historical weather data, and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

12,451 kWh/Year*

Month	Solar Radiation (kWh / m² / day)	AC Energy (kWh)
January	6.18	1,163
February	6.82	1,144
March	7.18	1,303
April	7.03	1,223
May	5.91	1,061
June	5.49	952
July	4.97	886
August	4.35	794
September	5.56	967
October	5.59	1,029
November	4.85	887
December	5.49	1,042
Annual	**5.79**	**12,451**

Location and Station Identification

Requested Location	ilocos norte
Weather Data Source	Lat, Lng: 18.21, 120.58 1.3 mi
Latitude	18.21° N
Longitude	120.58° E

PV System Specifications

DC System Size	8 kW
Module Type	Standard
Array Type	Fixed (roof mount)
System Losses	14.08%
Array Tilt	20°
Array Azimuth	180°
DC to AC Size Ratio	1.2
Inverter Efficiency	96%
Ground Coverage Ratio	0.4
Albedo	*From weather file*
Bifacial	No (0)

Monthly Irradiance Loss

Jan	Feb	Mar	Apr	May	June
0%	0%	0%	0%	0%	0%

July	Aug	Sept	Oct	Nov	Dec
0%	0%	0%	0%	0%	0%

Performance Metrics

DC Capacity Factor	17.8%

Figure G7. PVWatts Calculation Results for 8 kWp PV Setup.

Caution: Photovoltaic system performance predictions calculated by PVWatts® include many inherent assumptions and uncertainties and do not reflect variations between PV technologies nor site-specific characteristics except as represented by PVWatts® inputs. For example, PV modules with better performance are not differentiated within PVWatts® from lesser performing modules. Both NREL and private companies provide more sophisticated PV modeling tools (such as the System Advisor Model at //sam.nrel.gov) that allow for more precise and complex modeling of PV systems.

The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

The energy output range is based on analysis of 30 years of historical weather data, and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

18,677 kWh/Year*

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	6.18	1,745
February	6.82	1,716
March	7.18	1,954
April	7.03	1,835
May	5.91	1,591
June	5.49	1,428
July	4.97	1,330
August	4.35	1,192
September	5.56	1,450
October	5.59	1,543
November	4.85	1,330
December	5.49	1,564
Annual	5.79	18,678

Location and Station Identification

Requested Location	ilocos norte
Weather Data Source	Lat, Lng: 18.21, 120.58 1.3 mi
Latitude	18.21° N
Longitude	120.58° E

PV System Specifications

DC System Size	12 kW
Module Type	Standard
Array Type	Fixed (roof mount)
System Losses	14.08%
Array Tilt	20°
Array Azimuth	180°
DC to AC Size Ratio	1.2
Inverter Efficiency	96%
Ground Coverage Ratio	0.4
Albedo	*From weather file*
Bifacial	No (0)

Monthly Irradiance Loss

Jan	Feb	Mar	Apr	May	June
0%	0%	0%	0%	0%	0%

July	Aug	Sept	Oct	Nov	Dec
0%	0%	0%	0%	0%	0%

Performance Metrics

DC Capacity Factor	17.8%

Figure G8. PVWatts Calculation Results for 12 kWp PV Setup.

NREL

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The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

The energy output range is based on analysis of 30 years of historical weather data, and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

20,233 kWh/Year*

Month	Solar Radiation (kWh / m² / day)	AC Energy (kWh)
January	6.18	1,891
February	6.82	1,859
March	7.18	2,117
April	7.03	1,987
May	5.91	1,723
June	5.49	1,547
July	4.97	1,441
August	4.35	1,291
September	5.56	1,571
October	5.59	1,672
November	4.85	1,441
December	5.49	1,694
Annual	**5.79**	**20,234**

Location and Station Identification

Requested Location	ilocos norte
Weather Data Source	Lat, Lng: 18.21, 120.58 1.3 mi
Latitude	18.21° N
Longitude	120.58° E

PV System Specifications

DC System Size	13 kW
Module Type	Standard
Array Type	Fixed (roof mount)
System Losses	14.08%
Array Tilt	20°
Array Azimuth	180°
DC to AC Size Ratio	1.2
Inverter Efficiency	96%
Ground Coverage Ratio	0.4
Albedo	*From weather file*
Bifacial	No (0)

Monthly Irradiance Loss

Jan	Feb	Mar	Apr	May	June
0%	0%	0%	0%	0%	0%

July	Aug	Sept	Oct	Nov	Dec
0%	0%	0%	0%	0%	0%

Performance Metrics

DC Capacity Factor	17.8%

Figure G9. PVWatts Calculation Results for 13 kWp PV Setup.

NREL

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The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

The energy output range is based on analysis of 30 years of historical weather data, and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

31,128 kWh/Year*

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	6.18	2,909
February	6.82	2,859
March	7.18	3,257
April	7.03	3,058
May	5.91	2,651
June	5.49	2,380
July	4.97	2,216
August	4.35	1,986
September	5.56	2,417
October	5.59	2,572
November	4.85	2,217
December	5.49	2,606
Annual	**5.79**	**31,128**

Location and Station Identification

Requested Location	ilocos norte
Weather Data Source	Lat, Lng: 18.21, 120.58 1.3 mi
Latitude	18.21° N
Longitude	120.58° E

PV System Specifications

DC System Size	20 kW
Module Type	Standard
Array Type	Fixed (roof mount)
System Losses	14.08%
Array Tilt	20°
Array Azimuth	180°
DC to AC Size Ratio	1.2
Inverter Efficiency	96%
Ground Coverage Ratio	0.4
Albedo	*From weather file*
Bifacial	No (0)

Monthly Irradiance Loss

Jan	Feb	Mar	Apr	May	June
0%	0%	0%	0%	0%	0%

July	Aug	Sept	Oct	Nov	Dec
0%	0%	0%	0%	0%	0%

Performance Metrics

DC Capacity Factor	17.8%

Figure G10. PVWatts Calculation Results for 20 kWp PV Setup.

NREL

NATIONAL RENEWABLE ENERGY LABORATORY

The energy output range is based on analysis of 30 years of historical weather data, and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

32,684 kWh/Year*

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	6.18	3,054
February	6.82	3,002
March	7.18	3,420
April	7.03	3,210
May	5.91	2,784
June	5.49	2,499
July	4.97	2,327
August	4.35	2,085
September	5.56	2,538
October	5.59	2,701
November	4.85	2,327
December	5.49	2,736
Annual	**5.79**	**32,683**

Location and Station Identification

Requested Location	ilocos norte
Weather Data Source	Lat, Lng: 18.21, 120.58 1.3 mi
Latitude	18.21° N
Longitude	120.58° E

PV System Specifications

DC System Size	21 kW
Module Type	Standard
Array Type	Fixed (roof mount)
System Losses	14.08%
Array Tilt	20°
Array Azimuth	180°
DC to AC Size Ratio	1.2
Inverter Efficiency	96%
Ground Coverage Ratio	0.4
Albedo	*From weather file*
Bifacial	No (0)

Monthly Irradiance Loss

Jan	Feb	Mar	Apr	May	June
0%	0%	0%	0%	0%	0%

July	Aug	Sept	Oct	Nov	Dec
0%	0%	0%	0%	0%	0%

Performance Metrics

DC Capacity Factor	17.8%

Figure G11. PVWatts Calculation Results for 21 kWp PV Setup.

NREL

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The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

The energy output range is based on analysis of 30 years of historical weather data, and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

35,797 kWh/Year*

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	6.18	3,345
February	6.82	3,288
March	7.18	3,746
April	7.03	3,516
May	5.91	3,049
June	5.49	2,737
July	4.97	2,549
August	4.35	2,284
September	5.56	2,780
October	5.59	2,958
November	4.85	2,549
December	5.49	2,997
Annual	**5.79**	**35,798**

Location and Station Identification

Requested Location	ilocos norte
Weather Data Source	Lat, Lng: 18.21, 120.58 1.3 mi
Latitude	18.21° N
Longitude	120.58° E

PV System Specifications

DC System Size	23 kW
Module Type	Standard
Array Type	Fixed (roof mount)
System Losses	14.08%
Array Tilt	20°
Array Azimuth	180°
DC to AC Size Ratio	1.2
Inverter Efficiency	96%
Ground Coverage Ratio	0.4
Albedo	*From weather file*
Bifacial	No (0)

Monthly Irradiance Loss

Jan	Feb	Mar	Apr	May	June
0%	0%	0%	0%	0%	0%

July	Aug	Sept	Oct	Nov	Dec
0%	0%	0%	0%	0%	0%

Performance Metrics

DC Capacity Factor	17.8%

Figure G12. PVWatts Calculation Results for 23 kWp PV Setup.

NREL
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The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

The energy output range is based on analysis of 30 years of historical weather data, and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

38,910 kWh/Year*

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	6.18	3,636
February	6.82	3,574
March	7.18	4,071
April	7.03	3,822
May	5.91	3,314
June	5.49	2,975
July	4.97	2,770
August	4.35	2,483
September	5.56	3,022
October	5.59	3,215
November	4.85	2,771
December	5.49	3,258
Annual	**5.79**	**38,911**

Location and Station Identification

Requested Location	ilocos norte
Weather Data Source	Lat, Lng: 18.21, 120.58 1.3 mi
Latitude	18.21° N
Longitude	120.58° E

PV System Specifications

DC System Size	25 kW
Module Type	Standard
Array Type	Fixed (roof mount)
System Losses	14.08%
Array Tilt	20°
Array Azimuth	180°
DC to AC Size Ratio	1.2
Inverter Efficiency	96%
Ground Coverage Ratio	0.4
Albedo	*From weather file*
Bifacial	No (0)

Monthly Irradiance Loss

Jan	Feb	Mar	Apr	May	June
0%	0%	0%	0%	0%	0%

July	Aug	Sept	Oct	Nov	Dec
0%	0%	0%	0%	0%	0%

Performance Metrics

DC Capacity Factor	17.8%

Figure G13. PVWatts Calculation Results for 25 kWp PV Setup.

NREL
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The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

The energy output range is based on analysis of 30 years of historical weather data, and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

149,415 kWh/Year*

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	6.18	13,961
February	6.82	13,724
March	7.18	15,634
April	7.03	14,677
May	5.91	12,727
June	5.49	11,422
July	4.97	10,638
August	4.35	9,533
September	5.56	11,603
October	5.59	12,347
November	4.85	10,640
December	5.49	12,509
Annual	**5.79**	**149,415**

Location and Station Identification

Requested Location	ilocos norte
Weather Data Source	Lat, Lng: 18.21, 120.58 1.3 mi
Latitude	18.21° N
Longitude	120.58° E

PV System Specifications

DC System Size	96 kW
Module Type	Standard
Array Type	Fixed (roof mount)
System Losses	14.08%
Array Tilt	20°
Array Azimuth	180°
DC to AC Size Ratio	1.2
Inverter Efficiency	96%
Ground Coverage Ratio	0.4
Albedo	*From weather file*
Bifacial	No (0)

Monthly Irradiance Loss

Jan	Feb	Mar	Apr	May	June
0%	0%	0%	0%	0%	0%
July	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
0%	0%	0%	0%	0%	0%

Performance Metrics

DC Capacity Factor	17.8%

Figure G14. PVWatts Calculation Results for 96 kWp PV Setup.

CURRICULUM VITAE

Personal Information

Name	:	Jomel C. Felix
Date of Birth	:	April 08, 1995
Sex	:	Male
Civil Status	:	Single
Religion	:	Born Again
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Educational Background

2012-2017	:	Mariano Marcos State University College of Engineering, Batac City Bachelor of Science in Computer Engineering
2007-2011	:	Sta. Rosa National High School Brgy. 10, Sarrat, Ilocos Norte
2005-2007	:	San Bernabe Elementary School Brgy. 12, Sarrat, Ilocos Norte
2001-2005	:	San Martin BBC Elementary School San Jose Del Monte City, Bulacan

Present Occupation

Employer	:	Mariano Marcos State University
Workstation	:	College of Industrial Technology
Address	:	Brgy. 7-B, Laoag City
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Professional Qualifications

Certified Computer Engineer
December 2024

Career Service Eligibility Professional
August 2022