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Research Article

Understanding the Economic Benefits and Adoption Challenges of Grid-Tied Solar Photovoltaic Systems for Prosumers in a Local Electric Cooperative in South Cotabato, Philippines

Diane C. Dahan[1,2] and Jypzie M. Catedrilla[2*]

[1]South Cotabato II Electric Cooperative, Inc., General Santos City 9500, Philippines
[2]Information Technology and Physics Department, Mindanao State University – General Santos, General Santos City 9500, Philippines

*Corresponding author: jypzie.catedrilla@msugensan.edu.ph

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Abstract

Adopting solar photovoltaic (PV) systems is crucial for a sustainable energy transition. This study examines solar PV adoption among prosumers, who are both consumers and producers of electricity, in a local cooperative in the southern Philippines, analyzing billing data from all nine (9) available prosumers and conducting semi-structured interviews with five (5) consenting prosumers. The study shows that the payback period of the investment varies among prosumers, ranging from 7.44 years to 35.90 years. The findings highlight technological limitations, such as the lack of smart home integration, high installation costs, inadequate after-sales services, and the intermittency of solar PV, along with environmental factors such as insufficient waste management policies, the lack of maturity in the solar industry, onerous permitting requirements, and insufficient financial incentives, which significantly hinder the widespread adoption of solar PV systems. This study offers critical insights for policymakers and industry stakeholders seeking to accelerate solar PV deployment. To build upon these findings, future research should pursue larger-scale, longitudinal studies across broader regions. Such work must examine policy impacts, regional disparities, diverse prosumer profiles, maintenance costs, and utility perspectives to enhance generalizability.

Keywords: *solar photovoltaic systems, prosumers, economic benefits, adoption barriers, payback period*

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Introduction

Renewable energy is derived from sources that can be replenished naturally, such as solar energy, hydropower, geothermal energy, wind power, and biomass. Global warming, air pollution, depletion of natural resources, and dependence on fossil fuels are becoming of great concern to modern society. Thus, utilizing renewable energy sources will significantly help address these environmental issues we are currently experiencing. According to the International Renewable Energy Agency (2019), solar photovoltaic systems are one of the fastest-growing and most cost-competitive renewable energy sources. Moreover, the International Energy Agency (IEA, 2022) projects that solar PV will surpass coal by 2027. It suggests that distributed generation will be increasingly dominated by solar PV installations in the future.

The increase in solar adoption responds not only to local initiatives but also aligns with broader global and national efforts to achieve sustainable clean energy in the future. Sustainable

Development Goal 7 envisions having accessible and clean energy for all. It has goals to achieve by 2030, including ensuring that everyone has access to energy, increasing the share of renewable energy in the generation mix, and improving energy efficiency (GOAL 7: Affordable and Clean Energy, 2023).

In the Philippines, the National Renewable Energy Program (NREP) 2020–2040 provides a strategic framework for increasing the share of renewable energy in the power generation mix to 35% by 2030 (DOE, 2020). To facilitate this transition, various policies and regulatory mechanisms, including the net-metering program, have been implemented to promote the adoption of renewable energy technologies. A critical component of this transition is the deployment of grid-tied solar PV systems, which enable solar installations to be integrated into the distribution utility. A distribution utility is an entity that delivers electricity from transmission lines to end-users (residential, commercial, and industrial). Under the net-metering program, energy consumers who own solar PV systems are permitted to export surplus electricity to the grid through their respective electric cooperatives. Upon meeting the prescribed application and technical requirements, these consumers are authorized to connect their systems to the distribution network, thereby contributing to the broader objective of increasing renewable energy penetration in the power sector.

Consumers who generate and consume electricity, referred to as 'prosumers,' play a vital role in decentralized energy production. These prosumers, consisting of households and small businesses, not only utilize the electricity generated by their solar PV systems but also supply excess energy to the grid. By participating in net-metering agreements, prosumers actively contribute to energy sustainability while being formally registered and recognized by the distribution utility.

The net-metering program, established under the Renewable Energy Act of 2008 (Republic Act No. 9513), facilitates this process by allowing consumers with solar PV systems of up to 100 kW peak demand to export surplus electricity to designated distribution utilities, such as the South Cotabato II Electric Cooperative (SOCOTECO II). Regulated by the Energy Regulatory Commission (ERC), the program ensures that exported electricity is credited against the prosumer’s subsequent electricity bill, promoting financial incentives for renewable energy adoption. By aligning with national policies aimed at increasing renewable energy utilization, net metering serves as a key mechanism in fostering a more sustainable and resilient energy sector.

Although the net-metering program was introduced in 2008, the ERC only approved the implementing rules and regulations in May 2013 (Ducut, 2013). However, its adoption was initially slow due to stakeholder concerns about permitting procedures and associated costs (DOE, 2016). To address these challenges, the program’s rules were amended in 2019 to facilitate broader participation among residential and small-scale consumers. Consequently, participation increased, and by December 30, 2020, approximately 4,000 eligible prosumers, including households and small businesses, were actively engaged in the net-metering program, generating a total of 32.1 MW of electricity. Notably, 85% of prosumers were concentrated in Metro Manila (Department of Energy, 2022). Despite this national growth, SOCOTECO II had only nine prosumers successfully participating in the program as of December 2023.

In response to this challenge, previous studies have sought to understand better individuals' intentions to adopt solar PV systems. These studies have identified several factors influencing consumer behavior, including the price value of solar PV systems (Bekti et al., 2019; Lau et al., 2020; Vasseur & Kemp, 2015), income level (Ahmar et al., 2022; Bashiri & Alizadeh, 2018; Lan et al., 2021), education level (Filgueira et al., 2022; Jayaweera et al., 2018; Sommerfeld et al., 2017), environmental consciousness (Cheam et al., 2021; Jabbour Al Maalouf et al., 2024; Kesari et al.,2021), perceived ease of use and perceived usefulness (Ali et al., 2020; Bandara & Amarasena, 2018; Bouaguel & Alsulimani, 2022), and the perceived participation of neighbours (Irfan et al., 2021; Morrissey & Scheller, 2024; Opiyo, 2019).

Early research has also examined the barriers associated with the adoption of solar PV systems. Findings indicate that several factors hinder adoption, including policy-related constraints (Do et al., 2020; Lazdins et al., 2021; Shukla et al., 2018), high initial costs (Curtius, 2018; Garlet et al., 2019; Palm, 2018), limited access to financing (Obuseh et al., 2025; Ugulu, 2019; Sackey et al., 2020), perceived long payback periods (Lo et al., 2018; Lu et al., 2019; Mah et al., 2018), and insufficient government financial support (Khan & Nazir, 2022; Lau et al., 2022; Qureshi et al., 2017).

While existing literature contributes to a better understanding of solar PV adoption, a significant research gap remains. Much of the research focuses on non-adopters, offering theoretical insights into the factors influencing adoption decisions. However, despite the presence of enabling opportunities as supported by previous literature, SOCOTECO II has exhibited a slow adoption rate, indicating that challenges persist beyond the initial decision-making stage. Examining these barriers is crucial to understanding the disconnect between adoption potential and actual implementation. Moreover, understanding the experiences of actual solar PV adopters is essential in assessing whether the perceptions and expectations formed during the pre-adoption phase align with the realities observed in the post-adoption phase (Rai & McAndrews, 2012).

Given these concerns, this study focuses on the challenges encountered in the post-adoption phase, shedding light on the barriers that slow down solar PV systems integration within SOCOTECO II's service area and assessing the economic benefits of installation of solar PV systems, which includes analyzing changes in electricity consumption before and after installation, monthly and annual savings, and the overall payback period. This study aims to address the following research questions:

1. What are the economic benefits of installing solar PV systems in terms of the following:
    a. differences in consumption before and after installing solar PV systems
    b. annual savings
    c. Payback period?
2. What are the barriers to solar PV adoption for prosumers?

Relevant Literature

Solar energy is the electromagnetic energy radiated from the sun (Joseph & Wilkie, 2023). It is the most abundant energy resource available to human society. There are new technologies being used in the market now to generate electricity from the harvested solar energy. It can be utilized through two primary conversion methods: solar thermal and photovoltaic technologies (Asif, 2023). Solar thermal systems convert solar radiation into heat energy, whereas photovoltaic (PV) systems generate electricity through the photovoltaic effect. This study focuses on the latter.

There are two significant classifications of solar PV systems: stand-alone and grid-tied. Stand-alone systems are designed to operate independently from the distribution utility. It is a self-sufficient energy solution specifically beneficial for those residing in rural areas with limited access to the distribution utility. In contrast, grid-tied solar systems are connected to the distribution utility and enable the generation and distribution of electricity (Alsaidan et al., 2021). It can also be called grid-connected, on-grid, utility-interactive, grid intertie, or grid backfeeding. In this study, the term "grid-tied" will be employed to prevent ambiguity.

Economic Benefits

The payback period is a widely utilized metric for project evaluation, representing the duration required to recover the initial investment cost (San Ong & Thum, 2013). An investment is considered economically viable if its payback period is shorter than the anticipated service life or operational duration of the technical solution (Gorshkov et al., 2018). A simple payback period is often assessed before the adoption of solar PVs (Kessler, 2017). It better describes the value of electricity in terms of the product's sustainability. This computation is based on the initial capital cost of the investment and the avoided cost of the electricity based on the net-metering program. Also, Anderson and Newell (2004) found that the adoption rates of recommended energy projects are higher for projects with shorter payback periods, lower costs, more significant annual savings, higher energy prices, and greater energy conservation.

Sigrin and Drury (2014) conducted a study on the economic returns required for household adoption of solar PV systems. The study assessed the financial viability of solar PV systems, with most participants evaluating them based on monthly savings on electricity bills, followed by the computation of the payback period. Moreover, a similar economic analysis conducted by Shivalkar et al. (2015) computed energy consumption and its equivalent cost before the installation of solar PV, PV production per month, energy consumption and its equivalent cost after the installation of solar PV, monthly savings, annual savings, and payback period. The study concluded that solar PV systems offer significant benefits for consumers, utilities, and the environment.

Solar PV Systems Adoption

A study conducted in Akure, Nigeria, revealed low awareness of solar PV adoption. High costs and misconceptions about the capabilities of solar PV were also identified as hindrances to widespread adoption. However, many residents were willing to adopt the technology (Saka et al., 2017). Similarly, a study in Pakistan examined the social acceptability of solar PV systems in the area, emphasizing the role of government incentives in boosting adoption (Jan et al., 2020).). A study in Saudi Arabia found strong public acceptance of residential solar PV systems. However, financial constraints persisted, with many respondents supporting adoption only if there were government subsidies or if net-metering policies were implemented (Alrashoud & Tokimatsu, 2020).

Motivation and barriers to solar PV adoption were explored in a study in Nigeria, highlighting significant technological and socioeconomic challenges. Limited consumer education, fraudulent installers using substandard materials, and high installation costs discouraged adoption, even though many households sought alternatives to costly fuel-based generators (Ugulu, 2019). Similarly, in Northern Samar, Philippines, high awareness and satisfaction levels, with education and training playing crucial roles in adoption. While these studies emphasize factors enabling solar PV adoption, they also underscore the persistence of financial and informational barriers (Tan & Cornillez, 2017).

Despite growing interest in solar PV technology, research on adoption barriers in the southern Philippines remains limited. Since the launch of the net-metering program in the country, only nine prosumers have participated in the initiative in the local electric cooperative in the southern Philippines that caters to nine (9) municipalities and one (1) highly urbanized city with 256,667 members, highlighting the slow adoption rate. Given the region's unique socio-economic and geographic conditions, further studies are necessary to understand the challenges that hinder solar PV implementation. Identifying these barriers can strengthen policies and interventions that promote wider adoption, ensuring that solar energy becomes a viable alternative for households in the region.

Theoretical Framework

Tornatzky and Fleischer's (1990) three-factor model of technological, organizational, and environmental forces (TOE) is used to examine the critical technology adoption factors at the organization level of analysis (Hwang et al., 2016). The theoretical framework describes the decision-making process to adopt new technology as a result of exchange relations among three extensive forces. First, the technologies that are relevant to the organization that are currently in use, as well as those available in the market but are not presently in use (Langefors, 2011). Second, the organization's characteristics, such as resources, training and skills, management support and change orientation (Lin, 2014). Lastly, organizations face competitive and technological pressures from internal and external environments, such as competitors, trading partners, customers, and government (Hwang et al., 2016). The main strength of the TOE framework is its flexibility to different organizational and technological contexts and adaptability to a new firm's situation (Lin, 2014). Based on literature review, the TOE framework is used to analyze adoption of solar PV systems for rural communities (Hatamifard et al., 2023), circular economy (Franco and Groesser, 2021) and general governance model (Jan et al., 2023).

The literature on solar PV systems highlights their critical role in sustainable energy transitions, emphasizing their technological classifications—stand-alone and grid-tied systems—and the economic considerations that influence adoption, such as payback periods and financial viability. Several studies point to the significant benefits of solar PV systems, including cost savings and environmental advantages, yet also reveal persistent challenges, particularly in developing countries. These include high upfront costs, limited awareness, misinformation, and a lack of government support or incentives. While there is strong interest and willingness to adopt solar PV in various contexts, adoption remains uneven, particularly in the southern Philippines, where net-metering participation is notably low despite substantial potential. To better understand these challenges, the Technological-Organizational -Environmental (TOE) framework serves as a helpful lens, offering a comprehensive approach to analyzing the interplay of technological readiness, organizational capability, and external pressures in the adoption process.

Methodology

Research Design

The study employed a qualitative descriptive design as an exploratory study. This approach was selected to achieve the research objectives of examining the demographic profiles of prosumers, the economic benefits of solar PV adoption, and the various enablers and barriers they face. The rationale for this design aligns with the purpose of qualitative research, which seeks to understand individuals' underlying beliefs, experiences, attitudes, behaviors, and interactions (Pathak et al., 2013). Furthermore, this methodology is well-suited for identifying emerging trends and exploring complex issues where thought and opinion are not yet fully formed or understood (Tenny et al., 2022), making it ideal for investigating a new phenomenon like prosumerism in this specific context.

Study Setting

The research was conducted in General Santos City, a key urban center in the southern Philippines. The specific context for this study is the service area of the South Cotabato II Electric Cooperative, Inc., also known as SOCOTECO II. This utility provider serves a significant customer base of 121,541 member-consumer-owners within the city. This setting underscores the core focus of the research, as it reveals a striking contrast: despite the large population of energy consumers served by the cooperative, the number of prosumers—those who both consume and produce energy—is remarkably small. The study notes that within this entire service area, only nine prosumers were identified, comprising seven residential and two commercial entities. This minimal population establishes the novelty of the subject and highlights the importance of studying this specific group.

Sampling

The sampling technique used was purposive sampling, a non-probability method where participants are selected based on their specific characteristics relevant to the research question. In this case, the entire known population of nine prosumers in the SOCOTECO II service area was selected for the study. This constitutes a census sampling approach for this unique group. However, the final sample size was determined by participation rate. Of the nine prosumers identified and invited, only five agreed to participate in the interviews, forming the final study participants.

Instrument

To assess the economic benefits of solar PV system installation, the study utilized data from SOCOTECO II's billing system, including ledger reports of monthly electricity bills, historical energy consumption, and net-metering installation records. The analysis focused on pre- and post-installation consumption and costs, annual savings, and the payback period. The variables used were adopted from the study of Shivalkar et al. 2015.

To examine the enablers and barriers to solar PV adoption, semi-structured interviews were conducted using a protocol adapted and modified from the work of Alrashoud and Tokimatsu 2020. In line with the approach described by Dearnley 2005, participants were encouraged to share their experiences through open-ended questions, while probing techniques such as follow-up questions, requests for examples, and prompts for elaboration were used to explore key themes from the conceptual framework.

Data Collection

Data collection began after securing ethics approval. A formal letter of invitation and an informed consent form were sent to nine prosumers, offering them the option to participate either face-to-face or online. Five respondents agreed to participate, with four choosing face-to-face interviews and one choosing online video conferencing via Zoom. The average duration of the interviews was approximately 90 minutes. Permission was also obtained from SOCOTECO II management to access billing records for document analysis, which supported the evaluation of the economic benefits of solar PV installation.

Data Processing and Analysis

The billing data from SOCOTECO II underwent document analysis for the second section of the interview questions. According to Bowen (2009), document analysis is a systematic procedure for evaluating printed and computer-based material. These documents may include books, magazines, and minutes of the meeting, journals, letters, charts, newspapers, organizational or institutional reports, and other public records. It can all be found in libraries, organizations, or institutional files. The paper collected data from SOCOTECO II's billing system, including ledger reports of prosumer's monthly electricity bill, historical energy consumption, and net-metering installation records that provides necessary data on consumption, cost, and savings associated with installing solar PV and applying the net-metering program from SOCOTECO II. Then, the data gathered were presented in tables and bar graphs for further analysis.

The payback period in years was determined using the formula derived from the research conducted by Shivalkar et al. (2015).

Payback period = Cost of the Entire Solar PV System/Annual Savings

The cost of the entire solar PV system is obtained from the responses during the semi-structured interview. On the other hand, the annual saving is computed using the ledger reports of the monthly electric bill data gathered from the SOCOTECO II billing system, which is calculated as follows:

Annual Savings = Amount of Average Monthly Solar PV production in x 12 months

Lastly, the interview responses were analysed using thematic analysis. The collected data, primarily nonquantitative, consisted of textual materials such as interview transcripts, field notes, and documents, as well as other visual materials documenting participants' experiences (Saldana, 2014). The study employed a deductive approach using a codebook based on the TOE model of Tornatzky et al. (1990). Fereday et al. (2006) emphasized that adopting a codebook enhances the rigor and trustworthiness of coding analysis. However, the study remained open to identifying significant codes derived from participants' own words. Emergent themes were incorporated into the codebook as respondents shared perspectives beyond the predefined codes or those deemed more relevant to the study. This approach enabled the identification and exploration of patterns, themes, and meanings related to the effects of solar PV adoption on prosumers. The theoretical framework guided the analysis, with predetermined codes derived from existing literature. However, flexibility was maintained to accommodate emerging codes, ensuring a critical evaluation of the coding scheme and participant data.

Validity of Results

One method that researchers extensively use to ensure research quality is member checking (Smith & McGannon, 2018). Member checking, also known as 'participant validation,' was popularized in qualitative research by Lincoln and Guba (1985), wherein participants assess the trustworthiness of the data and results derived from the study. In this research, member checking was employed to validate the credibility of the qualitative data and findings. The themes generated from the interview transcripts were presented to the participants during the validation process, and they were asked to confirm whether the data accurately reflected their experiences. All participants signed a certification of approval, affirming the accuracy of the results. Therefore, the findings are considered credible, reinforcing the validity of the research.

Ethical consideration

The study upholds ethical principles by prioritizing informed consent, ensuring participants are treated as independent individuals capable of deciding their involvement while being protected from potential harm. Voluntary participation is emphasized, granting individuals the freedom to join or withdraw without coercion. Gender and cultural sensitivity are integral, fostering an inclusive and respectful research environment that values individual differences. This study carefully considers interactions, tone, and gestures to prevent cultural biases and ensure equitable treatment of all participants. Additionally, the study obtained ethics approval, reinforcing its commitment to ethical research practices and the protection of participants' rights.

Results and Discussion

The study shows that solar PV adoption may benefit either gender; most prosumers are self-employed, earn more than P50,000.00 monthly, and are homeowners. The prosumers of solar PV systems come from various industries: power generation, tourism, consultancy, healthcare, and one being retired. It demonstrates the widespread adoption of solar PV systems across different professional fields. The presence of one adopter from the generation sector is noteworthy, as this individual has a deeper understanding of renewable energy systems and the advantages of using solar energy. Also, the majority of prosumers are couples with children. Thus, household size has a substantially positive effect on solar PV adoption. Ahmar et al. (2022) found that larger families often require more energy than smaller families, and they choose solar PV as their alternative source of energy to fulfil their daily needs.

Table 1 shows that the majority of the prosumers are categorized as residential customers, while only two prosumers are classified as commercial customers. With a standard deviation

Table 1.

List of Prosumers by Load Requirement and Customer Classification

Count	Code	Solar PV Capacity (kW)	Customer Classification	Operations Effective Date
Prosumer 1	P1	3.00	RES^a	24-Sep-19
Prosumer 2	P2	5.34	COM^b	19-May-21
Prosumer 3	P3	4.45	RES	11-Aug-21
Prosumer 4	P4	2.67	RES	09-Nov-21
Prosumer 5	P5	7.12	RES	07-Jul-22
Prosumer 6	P6	6.13	RES	27-Jul-23
Prosumer 7	P7	4.50	RES	24-Apr-23
Prosumer 8	P6	4.50	RES	31-May-23
Prosumer 9	P9	10.68	COM	13-Jun-23

[a] RES = Residential; [b] COM = Commercial;

of 2.43 kW, the average system size of the solar PV systems installed by the prosumers is 5.38 kW. These results also align with data from Manila Electric Company (Meralco), which shows that most net-metering prosumers are classified as residential customers. The average size of a rooftop solar PV installation per household is 5.00 kW (Todoc, 2018), which can power two large refrigerators, one four-hp air conditioner, a fan, and some lights (Si & Si, 2019). In this study, “some lights” is operationally defined as approximately eight (8) LED bulbs, each rated at 5 watts.

The SOCOTECO II net-metering program, which began in 2019, is being applied to qualified individuals. The installed solar PV system has a capacity that varies depending on the individual loads required by each prosumer. The most recent installation of P9 has the highest required load, while P4 has the lowest installed solar PV capacity.

Table 2 presents the average monthly energy consumption in kilowatt-hours (kWh) for each prosumer. All billing information was gathered from the billing system of SOCOTECO II. The average monthly energy consumption was divided into three time periods: before solar PV installation, during solar PV production, and after solar PV installation. This classification demonstrates the impact of installing and integrating solar PV systems. The average monthly energy consumption before the solar PV installation represents the consumption during the period the prosumer was entirely dependent on SOCOTECO II for their electricity needs. It means that SOCOTECO II supplied all energy, and there was no contribution from the production of the solar PV systems. The average monthly energy consumption with solar PV production indicates the excess energy delivered by the solar PV systems to SOCOTECO II. It was not consumed on -site and then exported to SOCOTECO II, where it was credited under the net-metering program. The average monthly energy consumption after solar PV installation corresponds to the remaining quantity of energy drawn from SOCOTECO II following the installation. This value is lower than before the solar PV installation, as part of the energy is now supplied by the system.

The last column in Table 2 shows the percent reduction in energy consumption before and after the installation of solar PV systems. It demonstrates that installing solar PV systems yields economic benefits. The reductions in energy consumption after installing solar PV systems make solar energy investment attractive. All of the prosumers experienced a decrease in their energy dependency from the distribution utility. P3 experienced the highest reduction of 90%, indicating a correctly sized solar PV system that aligns with their needs, while P6 and P9 showed lower reductions of 6% and 9%, respectively. It suggests a possible need for a larger or more efficient system to better meet its energy needs.

Table 3 shows the average monthly cost of electricity in pesos (₱) presented for the same three time periods: before solar PV installation, with solar PV production, and after solar PV installation. The average monthly cost of electricity before solar PV installation is the total amount paid to SOCOTECO II when the prosumer is entirely dependent on the power supply from SOCOTECO II, and it is being paid in full. The average monthly cost of electricity with solar PV production is the amount credited to offset future bills of the

Table 2.

Average Monthly Energy Consumption in kilowatt-hours (kWh) from SOCOTECO II

Prosumer	Energy Consumed from SOCOTECO II Before Solar PV Installation	Energy Produced by Solar PV System	Energy Consumed from SOCOTECO II After Solar PV Installation	Percent Reduction in Energy Consumption from SOCOTECO II
P1	504	232	272	46%
P2	957	435	522	45%
P3	763	690	73	90%
P4	762	308	454	40%
P5	794	421	373	53%
P6	2320	135	2,185	6%
P7	1,093	228	865	21%
P8	785	299	486	38%
P9	1,158	46	1,112	4%

Table 3.

Average Monthly Consumption in Peso (₱)

Prosumer	Before PV Installation	With Solar PV Production	After Solar PV Installation	Percent Reduction in the Cost of Electricity paid to SOCOTECO II
P1	3,882.67	1,343.79	2,543.90	34%
P2	7,048.19	2,801.04	4,247.14	40%
P3	4,625.42	3,946.43	678.99	85%
P4	6,379.95	1,994.00	4,385.95	31%
P5	5,946.00	2,491.55	3,454.45	42%
P6	22,086.13	845.78	21,240.35	4%
P7	9,782.53	1,433.61	8,348.92	15%
P8	6,082.64	1,818.13	4,264.50	30%
P9	10,976.14	178.49	10,797.66	2%

prosumers. The average monthly cost of electricity after solar PV installation is the amount still paid to SOCOTECO II, considering the deductions of the costs of the energy exported from the solar PV systems.

The last column in Table 3 presents the percent reduction in the cost of electricity paid to SOCOTECO II. All of the prosumers experienced a reduction in their monthly payment to SOCOTECO II. It confirms that solar PV systems effectively reduce the expenses paid to the distribution utility. Still, P3 has the highest reduction at 85% and P6 and P9 have slight decreases of 4% and 2%, respectively. Although it can be observed that both energy consumption and electricity costs were reduced after the installation of solar PV systems, the percent reductions in Tables 2 and 3 differ from each other due to the nature of the billing by distribution utilities. For instance, P3 reduced energy consumption by 85%, but the cost reduction paid to the distribution utility was only 42%. The exported energy is credited only at the generation rate, resulting in a significantly lower value than the rate paid for the energy delivered by SOCOTECO II, which includes various components such as generation, transmission, distribution, and government taxes. Therefore, the cost reduction is less than the reduction in energy consumption.

As a result, both Table 2 and Table 3 demonstrate the positive economic benefits of installing solar PV systems, which lead to a reduction in both energy consumption and electricity costs. Notably, prosumers who achieve the highest energy reductions also experience the most significant decrease in electricity costs.

Table 4 presents the number of months the solar PV systems have been in operation, along

Table 4.

Total Savings for Installing Solar PV Systems in Peso (₱)

Prosumer	No. of Months of Solar PV Installation	With Solar PV Production in Peso (₱)	Total Savings
P1	49	1,343.79	65,845.47
P2	5	2,801.04	14,005.21
P3	29	3,946.43	57,826.05
P4	6	1,994.00	23,678.55
P5	7	2,491.55	17,440.85
P6	17	845.78	14,378.30
P7	28	1,433.61	40,141.13
P8	5	1,818.13	9,090.67
P9	26	178.49	4,640.70

with the total savings. P1 has the most extended history of using solar PV systems and achieves the highest savings among all prosumers. On the other hand, P9 demonstrates that even after extended usage, the total savings are significantly reduced due to low solar PV production. Thus, it indicates that solar PV production has a significant impact on the total savings. P2 also has a high monthly output of P2,801.04, despite the solar PV systems being installed for only 5 months. It implies that efficient solar PV systems yield faster and greater returns.

Figure 1 illustrates a reduction in energy consumption from SOCOTECO II during the post-installation of solar PV systems. Each prosumer exhibits a different level of variance, with P3 reducing reliance on the grid by 90%, while P9 achieved only a 4% reduction. The case of P3 demonstrates that installing solar PV systems can be an effective strategy for reducing electricity bills and decreasing dependence on the grid. Since all prosumers experienced a reduction in energy consumption, solar PV systems prove to be effective in minimizing electricity costs.

The practical implementation of energy management practices optimizes solar energy usage, resulting in lower electricity bills. Reducing consumption is the first step toward a sustainable energy system; therefore, households that can balance their energy consumption with the electricity generated by solar PV systems will utilize solar energy more efficiently and sustainably (Kobus et al., 2013). However, variations in energy consumption patterns among prosumers are influenced by household demands, resulting in differences in annual savings and monthly electricity expenses. Thus, understanding electricity consumption in relation to daily household activity patterns is essential (Ellegård & Palm, 2011).

In this study, prosumers exhibit diverse usage patterns, with the majority referring to morning usage, during which they consume the most energy. It suggests that they had more household activities, resulting in higher demands during the early part of the day.

Table 5 shows the calculated payback period in years for installed solar PV systems, indicating that all prosumers can eventually recover their initial investment through bill savings. The payback period of solar PV systems varies among prosumers, ranging from 7.44 years to 35.90 years. The solar PV capacity, investment cost, and annual savings achieved influence this difference. With a system capacity of 6.13 kW, an investment cost of P250,000.00, and an annual savings of P33,612.50, Prosumer 2 has the shortest payback period of 7.44 years. The fastest return on investment is achieved by the one with a comparatively lower investment cost and higher annual savings. Prosumer 3, on the other hand, has the longest payback period of 35.90 years. The PV system's overall investment cost significantly delays the payback period, even if it offers the most extensive system capacity and the highest annual savings. The literature also emphasized that the payback period is substantially influenced by the investment cost (Winkler, 2015).

Figure 1.

Percent Reduction of Energy Consumption Before and After Installation of Solar PV Systems

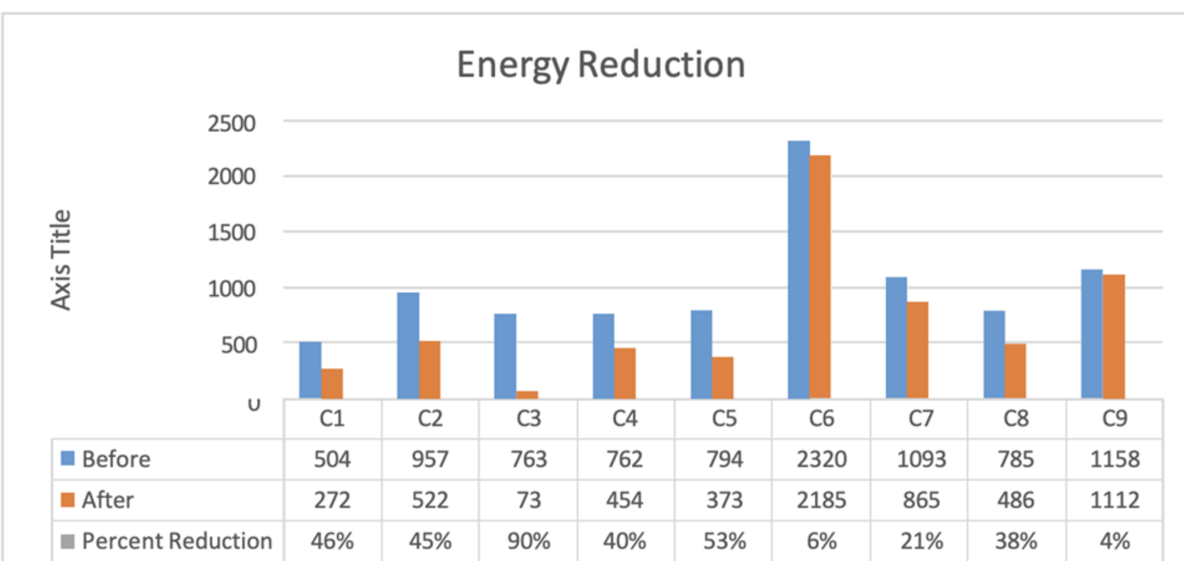


Table 5.

Computed Payback Period of the Installed Solar PV System

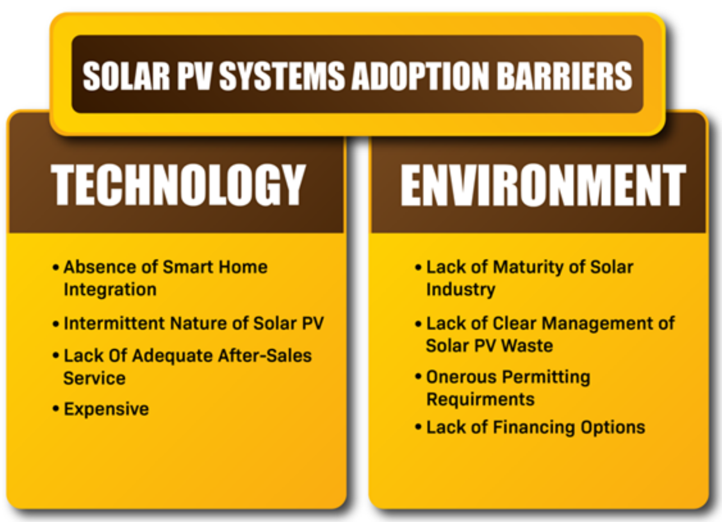
Prosumer	No. of Months	Total Cost of PV System	Annual Savings	Total Savings	Payback Period
P1	29	150,000.00	16,125.42	65,845.47	9.30
P2	5	250,000.00	33,612.50	14,005.21	7.40
P3	29	1,700,000.00	47,357.10	23,678.55	35.90
P4	6	300,000.00	23,928.02	57,826.05	12.5
P5	7	250,000.00	29,898.60	17,440.85	8.40
P6	17	Not Available	10,149.39	14,378.30	Not Available
P7	28	Not Available	17,203.34	40,141.13	Not Available
P8	5	Not Available	21,817.61	9,090.67	Not Available
P9	26	Not Available	2,141.86	4,640.70	Not Available

It illustrates how larger solar PV systems can provide more electricity, but their higher investment costs can also result in a longer return on investment.

Based on the data collected, the minimum payback period for recovering the investment in a solar PV system is 7 years. Scarpa & Willis (2010) stated that consumers expect their payback periods to be between 3 and 5 years, but in reality, it is more likely to be 10 to 15 years. The study shows that to yield shorter payback periods when investing in solar PV systems, the investment costs should be lower and have higher annual savings. Therefore, it is important to carefully consider both the annual savings and the investment costs when installing a solar PV system.

Figure 2.

Technological and Environmental Barriers to Solar PV System Adoption



Barriers in the Adoption of Solar PV Systems

For the second objective of the study, this section examines prosumers' actual experiences with installing solar PV systems. The findings were derived from interviews addressing the challenges associated with solar PV adoption. Figure 2 above categorizes the barriers to adopting solar PV systems into two main groups: technological factors and environmental factors, as no challenges emerged in the organizational factor, as this study focuses on the prosumers rather than organizational entities. This approach is consistent with the studies of Shakeel and Rajala (2020) on the barriers of solar PV adoption, which found that the

Table 6.

List of codes and their corresponding descriptions under the technological factor.

Codes	Code Description
Absence of Smart Home Integration	It refers to the lack of connection between solar PV systems and smart home technologies.
Intermittent Nature of Solar PV	It refers to the limitations of solar PV systems where solar energy production varies based on sunlight availability.
Lack of Adequate After-Sales Services	It refers to the insufficient support and services received by the users from their suppliers. It represents a lack of technical support for system maintenance.
Expensive	It refers to the high costs in terms of the product's affordability.

organizational factors were not applicable. Identifying these barriers in research and practice is crucial in understanding why the broader adoption of solar PV systems has not occurred (Reindl & Palm, 2021).

Table 6 presents a comprehensive list of codes along with their corresponding descriptions categorized under the technological factor.

Absence of Smart Home Technologies Integration

Most prosumers disagreed that solar PV is an innovative technology and has made their homes smart. Their responses reflect their broad perception of what constitutes a smart home. Prosumers currently utilize an app to monitor every aspect of their solar photovoltaic systems; however, some prosumers still need to integrate their appliances, lighting, solar PV systems, or other services with their existing internet-based infrastructure.

> P4: "*It's just one investment. It's more about internet-related if we say it's smart technology. It's just a part of it. If we say "smart home," it encompasses everything related to the internet.*"

The results show that the need for solar-powered smart home integration limits user convenience. El-Azab (2021) defines a smart home as a house with controlled energy schemes. It provides comfortable, fully controlled, and secure lifestyles to its occupants. Given the current state of technology usage, the majority of prosumers have not yet considered their homes as smart homes with the integration of solar PV systems. Prosumers missed out on the opportunity to have remote monitoring and automated energy management. It could lead to future users being less satisfied with the technology's overall performance and hinder current prosumers from fully utilizing its capabilities. Even though the 'smart home' is not a new scientific concept for society, it is still far away from people's vision and understanding (Shahin et al., 2017).

Therefore, integrating a smart home with the installation of a solar PV system is a recommended enhancement. Potential prosumers are encouraged to have their homes equipped with innovative technology before installing solar PV systems. They have options to implement smart home solutions provided by technical specialists, that ensure the smooth integration of solar PV systems into their residences. Future prosumers can surmount this obstacle by acquiring knowledge about smart integration and partnering with experts who can assist them in this regard.

Intermittent Nature of Solar PV

A prosumer disagreed with the notion that solar technology is a dependable technology because solar PV systems are limited by their reliance on sunlight for functioning. The intermittent nature of solar energy refers to the fluctuation in the output of the solar PV system due to varying solar irradiance (Azman et al., 2020).

> P2: "*No, it's not really reliable because as a consumer, you need a 24/7 power supply. When you sleep, you need the air conditioning. When you wake up, you cook. Usually, solar PV systems, these solar panels usually start around 6 or 7 AM. So, by 5, you're already waking up and cooking. By 6, there's still no supply, so you have to consume from the grid.*"

The prosumer emphasizes the need for a

consistent power source, hindered by the intermittent operation of solar PV installations. The timing of solar production does not align with the periods when the prosumers have a high demand. Thus, they consume more power from the distribution utility. Domestic households typically experience high periods of power demand in the early morning and evening, with lower demand during the day. It confirms that household activities peak in the early morning as people start using various appliances. Solar PV systems' generation, however, tends to peak in the middle of the day. It means that houses with solar PV systems often end up exporting energy to the distribution utility in return for payment during the day, and purchasing energy at standard electricity rates in the early morning and evening (Muenzel et al., 2015).

In this study, one prosumer adjusts and optimizes their energy usage to accommodate the intermittent nature of solar PV systems. The prosumer aligns their usage of air conditioning during the afternoon when the solar PV systems have maximum solar production. Therefore, the prosumer's experience highlights the importance of ensuring that the prosumers' expectations align with the solar PV production.

> P4: "*You're more conscious in the afternoon, especially now that it's hot, so you tend to use the air conditioning. At least you're not afraid to use it because you know it's covered by solar power.*"

Lack of Adequate After-Sales Services

Some prosumers reported that they knew someone who had stopped installing solar PV due to negative experiences with unreliable product suppliers. The negative experiences reveal significant challenges to the supplier's reliability and its after-sales service. This result supports the findings of Karakaya & Sriwannawit (2015), who found that weak and neglected after-sales service has also been shown to be a barrier to the diffusion of solar PV systems.

Wassie and Adaramola (2021) observed that solar PV adoption is influenced not only by economic and non-economic factors but also by critical challenges that affect the use and effectiveness of this technology. These include poor-quality products, counterfeit products from the market, and inadequate after-sales service and maintenance. Thus, all energy product suppliers should be as accurate as possible in their service, regardless of the prosumer's background, since any unplanned disturbance in the system's operations diminishes the attractiveness of the electricity service provided (Numminem & Lund, 2019).

> P3: "*It's not a reliable company. When we try to contact them, they will not respond anymore.*"

The lack of after-sales service support from solar PV system providers significantly affects the confidence of prosumers in the performance and business development of the technology. Similarly, Sibomana et al. (2019) also found that households receiving adequate after-sales support experience fewer system breakdowns compared to those receiving little to no assistance. With appropriate guidance from them, it not only enhances user satisfaction but also improves the system's reliability.

To address this issue, solar PV system providers should have warranty agreements and service contracts in place before installation. They should also strengthen their internal policies on after-sales services, ensuring that their employees regularly offer such services to customers. Apart from after-sales services, which mainly comprise delivery, installation, and warranty, they should also include a component of user training for demonstrating the usage of solar PV systems. The government should enforce policies to regulate solar PV system providers, protecting customers from substandard services from suppliers (Sibomana et al., 2019).

Expensive

One of the codes that emerged in this study is that all prosumers perceived the installation of solar PV systems as financially burdensome due to the high upfront investment cost relative to their household income and the long payback period.

> P2: "*There are a lot of calls, but it's difficult because it requires a large investment, and I can't mobilize easily because it's expensive.*"

The findings of this study emphasize the financial difficulties encountered in the adoption of solar PV systems due to their high investment costs. This is reinforced by the study of Mah et al. (2018), which found that the perceived high investment cost is the primary barrier to adoption. By ensuring that these technologies are affordable, they can become more appealing to potential prosumers and encourage wider adoption. To make solar PV systems more affordable, reducing the cost of the technology itself will lower their overall cost (Baurzhan et al., 2016). Financial support from the government can also ease the burden of investment costs, especially for low-income households (Lee & Shepley, 2020). Innovative financing models, such as

Table 7.

List of codes and their corresponding descriptions under the environmental factor.

Codes	Code Description
Lack of Maturity of Solar Industry	It suggests that the solar industry is still in its early stages of development.
Lack of Clear Policy for the Efficient Management of Solar Waste	It refers to the absence of specific government policies that aim to manage solar waste generated throughout
Onerous Permitting Requirement	It refers to how the present process for the application involved in solar PV systems is time-consuming and costly. This requirement stems from government and industry policy mandates.
Lack of Financing Options	It refers to a situation wherein the individuals have no financial resources for investment. If no local institutions offer loans, this reflects market/industry conditions (external to adopters).

microfinancing and the pay-as-you-go model, will enable households to afford the investment costs without incurring them upfront (Kumar et al., 2019).

Table 7 presents a comprehensive list of codes along with their corresponding descriptions, categorized under the environmental factor in the Technology-Organization-Environment (TOE) framework. In this context, the environmental factor encompasses external elements that influence the adoption of solar PV systems, such as government regulations, market conditions, energy policies, and infrastructure availability. These factors shape the overall feasibility of implementation by affecting costs, incentives, and compliance requirements. The table provides insights into the external conditions that either facilitate or hinder the adoption of solar PV technology.

Lack of Maturity of Solar Industry

A prosumer explicitly mentioned the lack of maturity in the solar industry, which is hindering the adoption of solar PV systems. Maturity in the solar sector refers to the stage where market, technology, and policy frameworks have developed stability and efficiency, resulting in the widespread adoption of solar PV systems (Barker & Bing, 2005).

> P2: "*I used to have solar, but nothing happened. Plus, suppliers would disappear, and warranties couldn't be honored. The market still hasn't matured*."

This comment is significant as it describes the current state of the solar industry and highlights the underlying issues of instability and lack of trust within the industry. For instance, Nel and Komendantova (2015) have noted similar concerns that the immaturity of renewable energy technologies leads to higher vulnerability, thereby increasing the risk. This theme warrants inclusion in this study.

It was also further contextualized by Reeves et al. (2017), who noted that prosumers in more mature markets are expected to place a higher value on local information channels, such as neighbors, friends, family members, and co-workers, than prosumers in less mature markets. In this instance, the prosumer attempted to persuade his friend to install solar PV systems, but the friend's resistance hindered the installation due to negative past experiences. It demonstrates that, as the market develops, the importance of positive experiences spread through local networks in raising adoption rates—a point the prosumer was attempting to make—will become more evident.

Lack of a Clear Policy for the Efficient Management of Solar PV Waste

One prosumer raised significant environmental concerns about the waste disposal of the solar PV system's components once their useful lives were over. While solar energy is considered an environmentally friendly source of energy, current policies for waste disposal are limited primarily because most components of solar PV systems have not yet reached the end of their lifespan (Almarshoud & Elragi, 2017). It can threaten the environment after its end of life if the disposal system is not well-maintained

(Tasnim, 2022).

> P2: "*During operation, we can say it is relatively clean. However, the issue arises throughout its entire lifecycle, from cradle to grave. While we may have a clear understanding of the initial stages—from conception and construction to its current operational phase—the question remains: What happens when it reaches the end of its lifespan? Where will it be disposed of? Is there an entity responsible for collecting it, recovering its components, and managing it properly to prevent environmental harm?*"

Various countries exhibit different gaps and challenges in their waste management policies for solar PV systems. In China and the United States of America (USA), both countries have implemented some policies; however, China lacks local policies at the government level, and the USA experiences inconsistencies in the policies imposed across states (Ali et al., 2023). In the United Arab Emirates (UAE), the absence of a global policy for waste disposal is evident, as local studies have shown that its extreme conditions result in the faster degradation of solar panels, leading to the premature generation of solar waste (Al-Ali et al., 2024). In Brazil, challenges in the design of the solar components, recycling technology, and economic feasibility are compounded by the lack of specific regulations (Souza et al., 2024). A common concern across all these cases is that existing policies are insufficient to manage the end -of-life disposal of solar PV system components, which can result in environmental hazards (Xu et al., 2024).

Furthermore, the uncertainty in the prosumer's response implies that these issues were not adequately addressed before the installation of the solar PV systems commenced. Thus, there should be improved and clear communication between the suppliers and prosumers regarding the waste disposal of the different components of solar PV systems (Ozcan & Al-Zarqawee, 2024). However, this effort must be supported by well-defined policies that cover all stages of a product's life cycle process, ensuring it is safe for the environment.

Onerous Permitting Requirements

Most prosumers shared their thoughts, views, and recommendations, particularly regarding the permitting requirements for installing solar PV systems. The first step involves obtaining permission from the Office of the Building Official, as obtaining a Certificate of Occupancy was mandatory before starting the installation process. This requirement was costly and time-consuming for prosumers with older homes lacking valid occupancy permits, whether because they were never required, had been lost, the structures had changed, or the original owners were no longer available (Philippine Solar and Storage Energy Alliance, 2024).

> P5: "*somewhat tedious part is the legislation, particularly with the Office of the Building Official (OBO).*"

The second factor is the time required to complete all requirements for the Local Government Unit (LGU), SOCOTECO II, and the Energy Regulatory Commission (ERC). The key requirements of the LGU include a building permit, an electrical permit, a fire safety inspection certificate, a certificate of final electrical inspection, and a certificate of occupancy (Si & Si, 2024). Additionally, the requirements of a distribution utility include a Certificate of Compliance form, identification documents, detailed planning data, a list of certified equipment, a Plant Parameters form, a Certificate of Compliance application fee, certification that the qualified end-user is technically compliant with the net metering interconnection, and a net metering agreement.

Furthermore, applying for a Certificate of Compliance (COC) with the ERC under the Net-Metering rules involves a net-metering contract, a distribution interconnection agreement, an affidavit of compliance, proof of regulatory fee payment, and a letter of endorsement from the distribution utility. Overall, the entire process will take 2 to 6 months to complete, from inquiry to a fully commissioned solar PV system (Pineda, 2025).

The experiences of prosumers are consistent with previous studies by Mogrovejo-Narvaez et al. (2024), Mathew & Nagaraja Pandian (2024), and Ibegbulam et al. (2023), which demonstrate that the permitting process associated with renewable energy projects has significantly hindered the country's adoption of solar PV. The permits should be simple, standardized, cost-efficient, and fast (Philippine Solar and Storage Energy Alliance, 2024, p. 35).

Lack of Financing options

The prosumers also recommended that the government establish a strong financing arm to encourage more people to choose renewable energy. The findings of Yousaf et al. (2021) support the notion that adequate funding support and the use of appropriate financing mechanisms are the most critical factors for program success.

> P4: "*So, the biggest part of improvement that needs to be done in solar to attract more adopters is financing. If we have a good financing arm, then maybe we could be more aggressive.*"

In this study, most prosumers financed their investment through personal savings, paying in full in cash. The dependability of prosumers in their savings aligns with their income profile, as the majority of prosumers earn above PHP 50,000.00 per month.

On the other hand, the presence of one prosumer who is retired and has no monthly income suggests that financial capacity alone is not a determinant of solar PV adoption, as this individual has utilized savings accrued during their retirement. Jayaweera et al. (2018) support this finding, as the likelihood of solar PV adoption may increase in the later stages of life, when affordability significantly increases due to income gained from retirement and pension.

International assistance, in the form of loans, grants, technical support, and cooperative alliances, is one way to help spread the adoption of solar PV systems (Ibegbulam et al., 2023). In Sub-Saharan Africa, the International Finance Corporation's (IFC) Scaling Solar programme has helped governments encourage private partnerships to build solar energy projects, as seen in Zambia and Senegal. Additionally, the Solar Market Gardens project was initiated by the Solar Electric Light Fund (SELF) in Benin, West Africa, in collaboration with regional groups and foreign funders. The project has improved the livelihood and sparked improvements in the community. The International Solar Alliance (ISA), led by France and India, helps developing countries by bringing nations together to address issues related to solar energy development, aiming to mobilize trillions of dollars of investment in solar energy by 2030.

Flexible payment schedules, loans from banks and other financial institutions with low interest rates, can also increase the adoption rate. The Pay-As-You-Go (PAYG) model, which originated in Kenya, allows users to make payments flexibly, paying for a small and manageable amount (Yadav et al., 2019). The Himbara Bank (a group of state banks) in Indonesia has committed to financing the installation of rooftop solar power plants with low interest rates and loan terms of up to 15 years (Rahman et al., 2024). Additionally, Malaysia introduced the Green Technology Financing Scheme (GTFS) in 2010 to support green energy technologies where the government guarantees 60% of the financing amount and a 2% interest rebate to reduce the financial burden on the borrowers (Ezuma & Matthew, 2022).

In the Philippine context, particularly the Department of Energy, should take the initiative to provide loans, incentives, and financing assistance to promote the widespread adoption of solar PV systems in the country. The initiatives will be strengthened by collaborating with financial institutions such as the Development Bank of the Philippines and the Land Bank of the Philippines, which can support financing schemes for green energy. On the other hand, the National Electrification Administration can support electric cooperatives in implementing the net-metering program by providing effective policies and technical assistance.

This study highlights key implications of solar PV adoption in General Santos City, where findings on payback periods (7.44-35.90 years) and investment cost impacts align with prior research (Gorshkov et al., 2018; Kessler, 2017; San Ong & Thum, 2013), confirming payback period as a critical viability metric. The results further support Shivalkar et al.'s (2015) demonstration of solar PV's financial benefits through reduced energy costs. Homeowners gain both immediate savings on electricity bills and long-term economic advantages, including ROI and potential property value increases, which may accelerate residential adoption and support sustainability goals. For stakeholders, these findings offer actionable insights: suppliers can refine marketing strategies, utilities can improve generation forecasting using prosumer data, and policymakers can develop more effective renewable energy programs. The study ultimately provides a benchmark for evaluating solar PV adoption trends and policy effectiveness nationwide.

Conclusions and Recommendations

This study aimed to understand the economic benefits and adoption challenges of grid-tied solar photovoltaic systems for prosumers in a local electric cooperative in South Cotabato, Philippines. The study shows that installing solar PV systems yields positive economic benefits. The reductions in energy consumption and the resulting annual savings on payments to the distribution utility after installing solar PV systems make solar energy investment attractive. Notably, prosumers who achieve the highest energy reductions also experience the most significant decrease in electricity costs. Additionally, larger solar PV systems can provide more electricity; however, their higher investment costs can also result in a longer return on investment.

On the other hand, the adoption of solar PV systems faces several challenges. Many prosumers do not see a solar PV system as innovative technology due to its limited integration with home automation. Its intermittent nature, reliant on sunlight, raises concerns about reliability, especially at night. Poor after-sales services and unreliable suppliers further discourage them from using the technology continuously. Expensive installation costs remain a significant impediment, while the industry's immaturity creates uncertainty and mistrust. Additionally, unclear policies on solar PV waste management, complex permitting processes, and a lack of financing options make adoption challenging for many prosumers.

Future adopters should be aware of the investment costs and the timeline for recovering their investment before making a decision. It can help them set realistic expectations about the system. In parallel, distribution utilities like SOCOTECO II should strengthen their outreach and education programs to increase awareness about solar PV systems and the net-metering program, and also to properly guide future prosumers about correct sizing and energy consumption management.

Implementing smart home integrations to optimize the economic advantages of installing solar PV systems is recommended for future prosumers. Before installation, they should inquire with their service providers regarding potential integration possibilities. They should also understand the limitations of solar energy before investing, as this particular energy source may not always be accessible, particularly during periods of low sunshine and at night.

The solar industry should strive to offer more cost-effective solar technologies and also to develop measures to enhance and sustain its after-sales assistance. Meanwhile, the government can create new regulations or incentive initiatives expressly designed to encourage the use of solar PV systems, and also implement a well-defined policy on the efficient management of solar PV waste that covers all stages of a product's life cycle. Lastly, the government must simplify permitting procedures to reduce the duration and expenses for future prosumers.

Since this study was limited to General Santos City and included only one commercial prosumer, future research should expand to the entire franchise area of the distribution utility or combine multiple distribution utilities to include a broader range of commercial and industrial prosumers. This would enable a more comprehensive analysis of both typical and outlier variations. Additionally, annual maintenance costs were not included in the financial calculations; future studies should incorporate these expenses to improve the accuracy of payback period and savings assessments. Further research could also incorporate the perspective of distribution utilities and examine regional or urban disparities in prosumer adoption to provide valuable insights. Longitudinal studies are recommended to track adoption trends, economic benefits, and user experiences over time. Finally, assessing the impact of incentives, subsidies, and regulatory frameworks could inform policy effectiveness. Finally, increasing the sample size in future studies would offer a more representative understanding of the prosumer experience with solar PV systems.

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