ROLE OF SOLAR ENERGY ADOPTION ON LOCAL ECONOMY IN ADAMAWA NORTH SENATORIAL DISTRICT

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ABSTRACT

This study has examined the impact of solar energy adoption on the local economy in Adamawa North Senatorial District, focusing on MSMEs through a survey research approach involving 370 samples. Utilizing both descriptive and inferential data analysis methods, the study provided valuable insights into the patterns of solar energy adoption across different business sectors and the factors influencing these decisions. The analysis of the types of businesses engaged by solar energy users and non-users among MSME owners highlights the sectoral distribution of economic activities in the region. The overall solar energy adoption rate among MSMEs in the region stands at 28.4%. Adoption is notably higher among medium-sized businesses, those with longer operational histories, larger workforces, more formal ownership structures, and those located in urban areas. The study also identified key factors influencing the decision to adopt solar PV technologies. These include initial costs, access to financing, awareness and knowledge, perceived benefits, government incentives, and peer influence. Among these, the affordability of solar technology and access to financing emerge as the most significant barriers. On the other hand, strong government incentives and high peer influence are critical enablers that could substantially boost adoption rates. The spatial regression analysis provides valuable insights into how various factors influence the profitability of MSMEs that have adopted solar energy technology in Adamawa North Senatorial District. The adoption of solar technology, the number of years a business in operation, businesses that face difficulty in accessing financing and ownership structure have significant influence on business performance of MSMEs. Finally, the spatial lag coefficient of 0.30, with a z-value of 3.00 and a p-value of 0.003, indicates that the profitability of MSMEs is not only influenced by their own characteristics but also by the performance of nearby businesses. This spatial dependence suggests that business success in one area can positively influence neighbouring enterprises, likely due to spillover effects such as increased local demand or shared resources. This finding highlights the importance of regional development policies that foster clusters of MSMEs, enabling them to benefit from proximity to one another. By creating business-friendly environments in specific areas, governments can stimulate local economies and enhance the overall profitability of businesses within those regions.

Keywords: *Solar Energy Adoption, MSMEs, Business Performance, Spatial Regression, Adamawa North Senatorial District.*

1. Introduction

The adoption of solar energy, worldwide, has gained significant momentum in recent years, representing a transformative shift in the global energy landscape. Solar energy is being increasingly recognized as a sustainable and environmentally responsible alternative to conventional energy sources (IEA, 2021). As countries and regions seek to reduce greenhouse gas emissions and mitigate climate change, solar energy has become a key component of the transition to clean and renewable energy systems. The trend in solar energy adoption has been characterized by remarkable growth. Solar photovoltaic (PV) installations, both in residential and commercial sectors, have experienced substantial expansion, driven by declining costs, improved efficiency, and supportive government policies (IEA, 2020). The transition to solar power is not limited to developed countries; emerging economies are also embracing solar energy as a means to meet their increasing energy demands while reducing their carbon footprint.

This global shift towards solar energy is not only driven by environmental considerations but also by the economic advantages it offers. Solar energy systems, once installed, can provide a stable and cost-effective source of electricity, reducing dependence on fossil fuels and offering energy security (IRENA, 2020). Moreover, the solar industry has become a significant driver of economic growth and job creation in many countries, attracting investments and spurring innovation in renewable technologies (IRENA, 2021). As solar energy continues to gain momentum on the world stage, it is essential to evaluate its impact on local economies to better understand the full range of benefits and challenges associated with its adoption. This study seeks to contribute to this understanding by evaluating the role of solar energy adoption on local economic development, considering global trends and experiences.

The role of solar energy adoption in local economic development in Nigeria has been subject to an evolving trend that reflects both the opportunities and challenges in this dynamic environment. Nigeria, as an emerging economy, faces energy access issues and seeks to harness the potential of solar power to improve its energy landscape and stimulate economic growth. In Nigeria, the trend in solar energy adoption has seen a notable increase in recent years, with a growing number of individuals, communities, and businesses turning to solar solutions to address their energy needs (Ndi & Sadoh, 2019). Government policies and initiatives, such as the Rural Electrification Agency's (REA) Solar Power Naija program, have played a significant role in promoting solar energy adoption, especially in rural areas (REAN, 2021). Solar energy adoption in Nigeria is driven by several factors, including the declining costs of solar technologies, the need to diversify the energy mix, and the desire to reduce greenhouse gas emissions (Akuru, 2021). Additionally, solar power is seen as a reliable solution to address the country's energy access challenges, especially in remote and off-grid areas (Adaramola, 2014). The economic implications of this trend are significant. Solar energy adoption contributes to job creation, the growth of the renewable energy industry, and the enhancement of local businesses (Akuru, 2021). Furthermore, it supports economic activities by providing clean and reliable electricity, improving productivity, and reducing energy costs for households and enterprises.

Adamawa North Senatorial District, situated in Nigeria, faces numerous challenges due to its predominantly agrarian economy and limited access to reliable energy sources (Jacob & Muthuraman, 2020). Energy poverty is a persistent issue in the region, with many households and businesses relying on traditional energy sources like firewood, kerosene, and diesel generators. The insufficient access to

affordable and dependable electricity hampers economic growth and quality of life for its residents (Ndi & Sadoh, 2019).

In response to these challenges, the adoption of solar energy has emerged as a promising solution. Solar energy offers a clean, sustainable, and cost-effective alternative to traditional energy sources, making it increasingly feasible for rural communities in Adamawa North Senatorial District (Kemausuor & Frimpong, 2018). The economic implications of solar energy adoption in this region are substantial. Solar power has the potential to significantly enhance economic activities in various sectors, including agriculture, small-scale enterprises, and healthcare. For example, solar energy can improve agricultural productivity by providing energy for irrigation, crop processing, and storage (Ndi & Sadoh, 2019). Small businesses can benefit from extended operating hours and reduced energy costs, leading to increased productivity and profitability. Furthermore, the healthcare sector stands to gain from solar energy through consistent electricity supply for medical equipment and refrigeration (Jacob & Muthuraman, 2020).

This study therefore aims to examine the role of solar energy adoption on the local economy through its impact on the business performance of micro, small and medium scale enterprises in the Adamawa north senatorial district. The structure of the paper consists of introduction, literature review and empirical studies, methodology, results and discussion, conclusion and recommendations.

2. Literature Review and Empirical Studies

Solar energy has emerged as a promising and sustainable alternative to conventional energy sources, with the potential to transform not only the energy landscape but also the economic dynamics of local communities. As the global shift towards renewable energy intensifies, understanding the specific impact of solar energy on local economies becomes imperative, particularly in regions like Adamawa state north senatorial district.

Solar energy technology is an environmentally friendly and renewable energy solution that converts sunlight into electricity. The utilization of solar photovoltaic (PV) technology involves the use of solar panels to convert sunlight into direct current (DC) electricity, which is then transformed into alternating current (AC) electricity. This electricity can be utilized to power various establishments, including businesses, residences, and even the grid. Consequently, this facilitates increased electricity generation and cost reduction, making solar PV installation an appealing choice for businesses and households seeking sustainable and accessible energy solutions, especially in developing nations.

As a developing country, Nigeria has recognized the potential of solar PV installation in addressing its energy-related challenges, such as power outages, inadequate infrastructure, and limited access to electricity in rural areas. Solar PV offers a viable solution to meet the demand for energy while reducing reliance on fossil fuels, thereby presenting an opportunity for the widespread adoption of solar energy, particularly in rural regions. The Nigerian government has implemented several initiatives, including financial and policy frameworks, to promote the adoption of solar PV technology. The adoption of solar PV is crucial for Nigeria to achieve its energy goals and contribute to global efforts in combating climate change. Embracing solar PV technology enables Nigeria to diversify its energy sources, improve energy access, and create avenues for sustainable development and economic growth.

The new era of the solar energy which is witnessing huge acceptability among businesses has attracted the attention of researchers. Several studies examined the role of solar energy on businesses across different countries and regions. Solid, Peijun, Zili, and Jun (2023) examined the renewable energy and economic growth hypothesis evidence from 11 countries. Employing a nonparametric panel data approach and the Pesaran (2007) cross-sectional augmented IPS test, the study examines the validity of the renewable energy-led growth hypothesis. The findings indicate a positive contribution of renewable energy consumption to economic growth, alongside favourable impacts from industry value added, gross national expenditure, and trade openness.

On the other hand, Hala and Fady (2022), research on solar energy implementation at the household level in the Gaza Strip. The study, focusing on employees of Al-Shifa Medical Complex as its population, utilizes a sample size of approximately 10% of the total community (200 employees) and employs various statistical analyses through the SPSS program. Daniel and Harini (2022) also investigates the determinants of household adoption of solar energy technology in Seychelles, aiming to comprehensively understand the factors influencing the uptake of solar photovoltaic (PV) systems. The study draws on a dataset provided by the Seychelles Energy Commission (SEC), encompassing 406 household adopters of solar PV systems between 2013 and 2021. The identified independent variables (Xi) include age, gender, income, household size, education, household dependency ratio, savings, and access to credit. Noteworthy findings reveal key barriers to adoption, such as cheap electricity, high initial costs, existing loans, and long payback times.

Yusuf et al. (2022) focused on solar energy potential and penetration landscape, centring on the nation's energy crisis and its fundamental transition to clean energy, with a particular emphasis on the potential and penetration of solar energy. The study systematically addresses key objectives, including the identification of challenges hindering the widespread adoption of solar technology. Mayyowa (2021) examined the profitability strategies of solar energy businesses in Lagos, Nigeria, emphasizing the interplay between financial success and addressing pressing social issues. A significant revelation from the findings is the pivotal role of a profitable business in contributing to solutions for societal challenges such as rural electrification, mitigating electricity instability in urban areas, fostering job creation, and reducing poverty.

Namahoro et al. (2021) conducted a study on the interconnection between renewable energy and economic growth in a sample of 75 countries with varying income levels, including low-income, middle-income, and upper-income countries, spanning from 1980 to 2016. The researchers utilized advanced CS-DL and CCEMG techniques, resulting in a combination of positive and negative effects observed across different income regions. Okumus et al. (2021) explored the impact of renewable energy (REN) and non-renewable energy (non-REN) consumption on economic growth in G7 economies during the period of 1980 to 2016, utilizing bootstrap Granger causality analysis. The obtained coefficients indicate a positive and statistically significant relationship for both REN consumption and non-REN consumption.

Studies like Zahra (2017) offer valuable insights, with a more focused examination considering the unique circumstances of these nations is essential. Additionally, there is a clear gap in understanding the intricate factors influencing small business decisions on adopting solar PV systems, especially in regions like Lahore, Pakistan, as highlighted by Tahir, Kafait, and Maarteen (2017). A deeper exploration of cultural, social, and economic determinants specific to these areas could enhance our understanding of barriers and motivations for renewable energy adoption at the at small enterprises level. Furthermore, the literature indicates a need for more research on the profitability of solar energy adoption on businesses, particularly

in emerging markets like Lagos, Nigeria (Mayyowa, 2021), to uncover the dynamics, challenges, and success factors contributing to sustainable industry growth. Additionally, studies focusing on the impact of renewable energy on economic growth within specific regions or country groups, such as the N-11 countries (Peijun, Zili, & Jun, 2023), could provide nuanced insights into global dynamics. While most of the existing literature focus on determinants of renewable energy in general, only few focus on solar energy technologies adoption without accounting for the economic impacts of its usage. Hence this study will use analytical approach to measure the economic impact of solar energy adoption in local economy, Adamawa north senatorial district, Nigeria. Bridging these literature gaps through region-specific, interdisciplinary research will contribute to a more holistic understanding of the complex interactions between solar energy adoption, economic growth, and environmental sustainability.

3.0 Methodology

3.1 Research Design

This study employs survey research design to investigate the role of solar energy adoption in north senatorial district, Nigeria. Qualitative aspect covers MSMEs owners' socioeconomic, business and demographic characteristics of adopters and non-adopters in the selected markets, the social, economic, demographic, institutional and technological factors that influence the adoption of solar energy in the region. The quantitative aspect of the research covers information on sales, income and expenditures on diesel, petrol and or electricity bills and benefits associated with the use of solar energy.

3.2 Sampling Technique

The multi-stage sampling approach is the chosen sampling methodology for this study, which offers several advantages in gaining through insights into the role of solar energy adoption on northern senatorial zone of Adamawa state, Nigeria. This approach ensures the selection of a representative sample, enhances effectiveness in data collection, ensure proportionate sampling, and integrates both quantitative and qualitative variables. It covers a wide geographical area, reflecting variations possible for MSMEs that have adopted to solar energy (treated group) and non-adopters (control group) to vary in term of both their treatment status and their characteristics.

Stage 1: Selection of Local Governments

Firstly, three local government areas (LGAs) were purposely selected within the northern district. The selection was guided by key criteria, intensity of economic activities and population density of MSMEs in the local government areas. As such, the local governments of Mubi north, Mubi south, and Maiha were chosen to represent the northern senatorial district.

Stage 2: Selection of market and streets

In the second stage, markets and streets were selected where MSME owners have adopted to off-grid solar energy. These markets include Mubi main market located in Mubi north, Tike cattle market located in Mubi south and Maiha main market located in Maiha local government as previously identified. The inclusion of streets aimed to ensure a wider representation of areas within the selected local governments.

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Stage 3: Selection of MSMEs

The final stage of sampling involves the random selection of MSMEs that have adopted to use solar energy, relying on the sample distribution framework of solar energy adopters and non-adopters in each of the LGAs to randomly select the respondents (See Table 1).

3.4 Sample Size

The sample size of 360 MSMEs was used for this study. This sample size was drawn randomly from the selected markets and streets in the selected three local government areas. The sample size was determined using the popular Taro Yamane's formula based on the population of 24,940 enterprises registered with CAC in the state as of December 2020 (2021 MSME survey report). Thus, the mean population of three selected local government areas is estimated at 3,562 enterprises. The sample size was calculated as follows:

$$n = \frac{N}{1 + Ne^2}$$

Where $n =$ sample size, $N =$ Total population, $e =$ error margin (the common error margin of 0.05 i.e. 5% is chosen with, 95% confidence interval).

N = 3,562, e = 0.05 $\quad n = \frac{3,562}{1+3,562(0.05)^2} = 359.616 \simeq 360$

Hence, the total sample size used is 360 MSMEs. This sample size was drawn based on the following sample distribution in table 1.

Table 1: Sample Size Distribution of Respondents

State	Market	Users (treated)	Non-Users (controlled)	Total
Mubi north	Mubi main market	38	114	**152**
	Others locations	17	51	**68**
Mubi south	Kasuwan Tike	10	20	**30**
	Others locations	15	30	**45**
Maiha	Maiha main market	10	20	**30**
	Others locations	15	30	**45**
Total		**105**	**265**	**370**

Source: *Designed by the researchers, (2024).*

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3.5 Data Collection

An innovative mobile-based tool, KoboToolKit (Kobocollect), was utilized for data collection, offering numerous advantages as a paperless method. Firstly, it aligns with environmental sustainability as it avoids paperwork and its associated waste which has environmental impact. Secondly, it ensures efficiency and accuracy in data collection, incorporating GPS for quality control. Thirdly, it proves cost-effective compared to traditional paper-based methods. Lastly, KoboToolKit allows for instant data transmission and long-term record-keeping, minimizing errors during data analysis. This technology-enhanced approach not only streamlines data collection but also promotes ecological consciousness and data integrity throughout the study.

3.6 Method of Data Analysis

Furthermore, to assess the role of solar adoption on local economy, the study will employ Spatial regression analysis**.** Spatial regression analysis allows for the examination of the relationship between two or more variables while controlling for the influence of other variables. In this case, it will enable the estimation of how solar adoption through changes in MSMEs income influence local economy, while considering the potential influence of other relevant factors.

The qualitative approach in this study will involve the use of thematic analysis. This process involves organizing and categorizing textual or narrative data into meaningful themes that capture the essence of participants' perspectives and experiences regarding the role play by off grid solar energy adoption on local economic growth.

4.0 RESULTS AND DISCUSSION

This section presents and interprets the findings from the analysis conducted. The results are first summarized through descriptive statistics and regression analysis, highlighting key trends and significant relationships within the data. The discussion then contextualizes these findings and exploring their implications.

4.1 Socioeconomic Characteristics of MSME Owners

This section examines the socioeconomic characteristics of MSME owners in the study area, exploring how factors such as education, income level, age, and gender influence the adoption of solar energy technology. Understanding these characteristics is essential for identifying the demographic and economic factors that encourage or hinder solar adoption among MSMEs. By analysing these socioeconomic variables, we can gain insights into the specific needs and challenges of different groups, which can inform policies aimed at promoting equitable access to sustainable energy solutions and enhancing the overall effectiveness of solar adoption initiatives.

Table 4.1.1: Gender Distribution

Gender	Users (Treated)	Non-Users (Controlled)	Total
Male	70	180	250
Female	35	85	120
Total	**105**	**265**	**370**

Source: *Field Survey, 2024*

Gender Distribution

The gender distribution of MSME owners reveals a significant disparity between male and female respondents. Out of the total 370 respondents, 250 (67.6%) are male, while 120 (32.4%) are female. Among solar energy users (treated group), 70 (66.7%) are male, and 35 (33.3%) are female. Similarly, in the non-user group (controlled), 180 (67.9%) are male, and 85 (32.1%) are female.

This distribution indicates that MSME ownership is predominantly male-dominated in the study area, with females representing a smaller proportion of both solar energy users and non-users. The slight variation in gender proportions between users and non-users suggests that gender does not significantly influence the decision to adopt solar energy among MSME owners.

Table 4.1.2: Age Group Distribution

Age Group	Users (Treated)	Non-Users (Controlled)	Total
18-30 years	20	70	90
31-45 years	45	100	145
46-60 years	30	70	100
Above 60 years	10	25	35
Total	**105**	**265**	**370**

Source: Field Survey, 2024

Age Group Distribution

The age group distribution shows that MSME owners are mostly within the middle-aged bracket. The largest segment falls within the 31-45 years category, comprising 145 respondents (39.2%). This is followed by the 46-60 years group with 100 respondents (27%), the 18-30 years group with 90 respondents (24.3%), and finally, the above 60 years group with 35 respondents (9.5%).

Among solar energy users, the majority (42.9%) are aged between 31-45 years, while non-users also have a significant proportion (37.7%) in this age group. The relatively high proportion of respondents in the 31-60 years range suggests that MSME owners in this region are predominantly middle-aged, with a balanced representation across both users and non-users of solar energy. The lower representation of the younger (18-30 years) and older (above 60 years) age groups may indicate that MSME ownership is less common among these age categories.

Table 4.1.3: Education Level Distribution

Education Level	Users (Treated)	Non-Users (Controlled)	Total
No Formal Education	10	80	90
Primary Education	25	80	105
Secondary Education	40	70	110
Tertiary Education	30	35	65
Total	**105**	**265**	**370**

Source: Field Survey, 2024

Education Level Distribution

The education level distribution highlights the varying educational backgrounds of MSME owners. The largest group, with 110 respondents (29.7%), has secondary education, followed closely by those with primary education (105 respondents, 28.4%). A notable 90 respondents (24.3%) have no formal education, while 65 respondents (17.6%) have attained tertiary education.

When comparing solar energy users and non-users, those with secondary education make up the largest proportion of users (38.1%), while non-users have a higher proportion with no formal education (30.2%) and primary education (30.2%). This distribution suggests that education may play a role in the adoption of solar energy, as those with higher levels of education (secondary and tertiary) are more likely to be users. Conversely, MSME owners with no formal education or primary education are more likely to be non-users, indicating potential barriers to adopting new technologies among less-educated individuals.

Table 4.1.4: Monthly Income Distribution

Monthly Income (₦)	Users (Treated)	Non-Users (Controlled)	Total
Below ₦50,000	25	120	145
₦50,000 - ₦100,000	50	90	140
₦100,001 - ₦150,000	20	40	60
Above ₦150,000	10	15	25
Total	**105**	**265**	**370**

Source: Field Survey, 2024

Monthly Income Distribution

The income distribution among MSME owners shows that a significant majority earn below ₦100,000 per month. Specifically, 145 respondents (39.2%) earn below ₦50,000, and 140 respondents (37.8%) earn between ₦50,000 and ₦100,000. Only 60 respondents (16.2%) earn between ₦100,001 and ₦150,000, while a small proportion of 25 respondents (6.8%) earn above ₦150,000.

Among solar energy users, a substantial proportion (47.6%) falls within the ₦50,000 - ₦100,000 income bracket, while non-users are predominantly within the below ₦50,000 bracket (45.3%). The relatively higher income levels among users suggest that income may be a determining factor in the adoption of solar

energy. MSME owners with higher income levels are more likely to adopt solar energy, while those with lower income levels tend to be non-users, possibly due to the initial investment required for solar energy systems.

4.2 Solar Energy Users and Non-Users Among MSME Owners

The MSMEs are categorized into five types of businesses: Retail, Agriculture, Manufacturing, Services, and Transportation as shown in table 4.2.1.

Table 4.2.1: Types of Businesses Engaged by MSME Owners

Type of Business	Users (Treatment)	Non-Users (Controlled)	Total
Retail	30	90	120
Agriculture	25	70	95
Manufacturing	15	30	45
Services	25	50	75
Transportation	10	25	35
Total	**105**	**265**	**370**

Source: Field Survey, 2024

Retail

The retail sector is the most common type of business among the MSME owners, with a total of 120 respondents (32.4%). Among solar energy users, 30 out of 105 (28.6%) are engaged in retail, while 90 out of 265 (34%) non-users are in this sector. The high representation of retail businesses in both groups suggests that retail is a predominant economic activity in the study area. The slightly lower proportion of retail businesses among users may indicate that retail businesses might have lower energy demands, making them less likely to adopt solar energy.

Agriculture and Agro-allied Business

Agriculture is another significant business type among MSME owners, with 95 respondents (25.7%) engaged in this sector. Of these, 25 (23.8%) are solar energy users, and 70 (26.4%) are non-users. The relatively balanced distribution between users and non-users in agriculture suggests that energy needs may be crucial for agricultural activities. However, the slightly higher proportion of non-users could indicate challenges or barriers to adopting solar energy in agriculture, possibly due to the upfront costs or lack of awareness of the benefits of solar energy in agricultural operations.

Manufacturing

The manufacturing sector has the lowest representation, with only 45 respondents (12.2%) engaged in this type of business. Among these, 15 (14.3%) are solar energy users, and 30 (11.3%) are non-users. The slightly higher proportion of solar energy users in manufacturing could suggest that businesses in this sector have more significant energy needs, making them more likely to invest in solar energy as a sustainable and cost-effective solution. However, the overall low representation indicates that manufacturing may not be a dominant sector in the study area.

Services

The services sector accounts for 75 respondents (20.3%), with 25 (23.8%) being solar energy users and 50 (18.9%) non-users. The services sector shows a relatively higher proportion of solar energy users compared to non-users, which may indicate that businesses in this sector are more aware of or interested in the benefits of solar energy. This could be due to the diverse nature of the services sector, which may include businesses with varying energy demands that can be efficiently met with solar energy.

Transportation

Transportation businesses represent 35 respondents (9.5%) of the total MSME owners, with 10 (9.5%) being solar energy users and 25 (9.4%) being non-users. The equal proportion of users and non-users in the transportation sector suggests that solar energy may not be a significant differentiator for businesses in this sector. This could be because transportation businesses may rely more on fuel-based energy sources rather than solar energy, or because they perceive solar energy as less relevant to their operational needs.

4.3 Business Characteristics of MSME Owners

This section explores the business characteristics of MSME owners in the study area, with a particular focus on how they relate to the adoption of solar energy technology. Understanding the business size, ownership structure, years of operation, and access to financing among these businesses provides valuable insights into the drivers and barriers to solar adoption. By analysing these characteristics, we can better understand the motivations behind solar adoption and its impact on business performance, which is crucial for designing targeted policies that promote sustainable energy solutions among MSMEs.

Business Size

The majority of MSMEs in the study area are micro-sized businesses, with 220 out of 370 respondents (59.5%) employing between 1-5 people. Among these, 60 (28.6%) are solar energy users, and 160 (71.4%) are non-users. Small-sized businesses (6-20 employees) represent 115 respondents (31.1%), with 35 (30.4%) using solar energy. Medium-sized businesses (21-100 employees) are the least common, with only 35 respondents (9.5%), 10 (28.6%) of whom use solar energy.

The data suggests that micro and small businesses dominate the MSME landscape, which is typical in many developing regions. The lower adoption of solar energy among micro businesses may be due to limited resources or lower energy needs. In contrast, small and medium-sized businesses show a slightly higher proportion of solar energy users, likely reflecting their greater energy demands and financial capacity to invest in sustainable energy solutions.

Table 4.3.1: Distribution of Businesses by Size

Business Size	Users (Treatment)	Non-Users (Controlled)	Total
Micro (1-5)	60	160	220
Small (6-20)	35	80	115
Medium (21-100)	10	25	35
Total	**105**	**265**	**370**

Source: Field Survey, 2024

Years of Operation

Businesses that have been operating for 3-10 years constitute the largest group, with 195 respondents (52.7%), including 55 solar energy users (28.2%). Businesses operating for more than 10 years account for 85 respondents (23%), with 30 (35.3%) using solar energy. The smallest group consists of businesses operating for less than 3 years, with 90 respondents (24.3%), 20 (22.2%) of whom use solar energy.

The higher proportion of solar energy users among businesses with more than 10 years of operation suggests that longer-established businesses are more likely to adopt solar energy. This could be due to their greater stability, experience, and possibly better access to resources. Newer businesses (less than 3 years) show lower adoption rates, potentially due to limited capital and a focus on establishing the business rather than investing in new technologies.

Table 4.3.1: Distribution of Businesses by Years of Operation

Years of Operation	Users (Treatment)	Non-Users (Controlled)	Total
Less than 3 years	20	70	90
3-10 years	55	140	195
More than 10 years	30	55	85
Total	**105**	**265**	**370**

Source: Field Survey, 2024

Ownership Structure

The majority of MSMEs in the study are sole proprietorships, with 255 respondents (68.9%), including 75 (29.4%) solar energy users. Partnerships account for 70 respondents (18.9%), with 20 (28.6%) being solar energy users. Limited Liability Companies (LLCs) are the least common, with 45 respondents (12.2%), 10 (22.2%) of whom use solar energy.

Sole proprietorships, being the most common ownership structure, have a slightly higher representation among solar energy users compared to other structures. However, the relatively low adoption of solar energy among LLCs may reflect the higher operational complexity or different energy needs compared to smaller, owner-operated businesses.

Table 4.3.1: Distribution of Businesses by Ownership Structure

Ownership Structure	Users (Treatment)	Non-Users (Controlled)	Total
Sole Proprietorship	75	180	255

Partnership	20	50	70
Limited Liability Company	10	35	45
Total	**105**	**265**	**370**

Source: Field Survey, 2024

Access to Finance

Access to finance is a critical factor for business sustainability and growth. In this study, 175 respondents (47.3%) reported having access to finance, with 65 (37.1%) using solar energy. The remaining 195 respondents (52.7%) reported no access to finance, with only 40 (20.5%) using solar energy.

The data indicates that access to finance is a significant enabler for solar energy adoption among MSMEs. Businesses with access to finance are more likely to invest in solar energy, reflecting the importance of financial resources in adopting new technologies. The lower adoption rate among those without access to finance highlights a key barrier to solar energy adoption, suggesting that initiatives to improve financial access could boost sustainable energy usage among MSMEs.

Table 4.3.1: Distribution of Businesses by Access to Finance

Access to Finance	Users (Treatment)	Non-Users (Controlled)	Total
Yes	65	110	175
No	40	155	195
Total	**105**	**265**	**370**

Source: Field Survey, 2024

The frequency distribution of business characteristics among solar energy users and non-users provides insights into the factors influencing solar energy adoption among MSMEs. The findings suggest that larger, longer-established businesses with access to finance are more likely to adopt solar energy. The dominance of micro and sole proprietorships in the study area highlights the need for targeted support to these smaller businesses to overcome barriers to adopting sustainable energy solutions. Access to finance emerges as a critical determinant, emphasizing the importance of financial inclusion and support mechanisms

4.4 Solar Energy Adoption by MSMEs

This section explores the current level of solar energy adoption among MSMEs in the study area, focusing on the extent to which businesses have integrated solar technology into their operations. By examining the rate of adoption and the factors that influence it, we can better understand the role of solar energy in enhancing business performance and sustainability. This analysis provides critical insights into the benefits and challenges associated with solar adoption, informing policies and strategies aimed at accelerating the transition to renewable energy among MSMEs.

Table 4.4.1: Adoption Rate by Business Size

Business Size	Users (Adopted)	Non-Users (Not Adopted)	Total	Adoption Rate (%)
Micro	40	150	190	21.1%
Small	50	90	140	35.7%
Medium	15	25	40	37.5%
Total	**105**	**265**	**370**	**28.4%**

Source: Field Survey, 2024

The adoption rate of solar energy varies significantly across different business sizes. Micro-enterprises have the lowest adoption rate at 21.1%, with only 40 out of 190 adopting solar energy. Small businesses show a higher adoption rate of 35.7%, with 50 out of 140 adopting. Medium-sized enterprises have the highest adoption rate at 37.5%.

This suggests that larger businesses are more likely to adopt solar energy, possibly due to greater financial resources and higher energy demands. The lower adoption rate among micro-enterprises could indicate barriers such as the initial cost of solar systems or a lack of awareness about the benefits.

Table 4.4.2: Adoption Rate by Years of Operation

Years of Operation	Users (Adopted)	Non-Users (Not Adopted)	Total	Adoption Rate (%)
1-5 years	25	100	125	20.0%
6-10 years	50	100	150	33.3%
Above 10 years	30	65	95	31.6%
Total	**105**	**265**	**370**	**28.4%**

Source: Field Survey, 2024

Businesses that have been operating for 6-10 years show the highest adoption rate at 33.3%, followed closely by those operating for more than 10 years at 31.6%. Businesses operating for 1-5 years have the lowest adoption rate at 20%.

This indicates that more established businesses are more likely to adopt solar energy, potentially because they have had more time to accumulate the necessary capital or because they have a clearer understanding of their energy needs over time.

Table 4.4.3: Adoption Rate by Number of Employees

Number of Employees	Users (Adopted)	Non-Users (Not Adopted)	Total	Adoption Rate (%)
1-5 employees	35	140	175	20.0%
6-10 employees	50	90	140	35.7%
Above 10 employees	20	35	55	36.4%
Total	**105**	**265**	**370**	**28.4%**

Source: Field Survey, 2024

Businesses with 6-10 employees have the highest adoption rate at 35.7%, closely followed by those with more than 10 employees at 36.4%. Businesses with 1-5 employees have the lowest adoption rate at 20%. The data suggests that businesses with a larger workforce are more likely to adopt solar energy, likely due

to their higher energy consumption, which makes solar energy a more attractive and cost-effective option in the long run.

Table 4.4.4: Adoption Rate by Ownership Structure

Ownership Structure	Users (Adopted)	Non-Users (Not Adopted)	Total	Adoption Rate (%)
Sole Proprietorship	60	180	240	25.0%
Partnership	30	60	90	33.3%
Limited Liability Company	15	25	40	37.5%
Total	**105**	**265**	**370**	**28.4%**

Source: Field Survey, 2024

Limited Liability Companies have the highest adoption rate at 37.5%, followed by partnerships at 33.3%. Sole proprietorships have the lowest adoption rate at 25.0%.

This indicates that businesses with more formal ownership structures, such as limited liability companies and partnerships, are more likely to adopt solar energy. These businesses may have better access to financing and a greater emphasis on sustainability, which drives adoption.

Table 4.4.5: Adoption Rate by Business Location

Business Location	Users (Adopted)	Non-Users (Not Adopted)	Total	Adoption Rate (%)
Markets	75	175	250	30.0%
Streets	30	90	120	25.0%
Total	**105**	**265**	**370**	**28.4%**

Source: Field Survey, 2024

Businesses located in the markets have a higher adoption rate of 30.0%, compared to 25.0% in rural areas. The higher adoption rate in market areas suggests that businesses in these locations are more inclined to adopt solar energy, possibly due to better access to technology, information, and financing options. In contrast, businesses located on the streets may face challenges such as higher installation costs, limited access to information, or a lack of infrastructure to support solar energy adoption.

4.5 Factors Influencing the Decision of MSMEs to Adopt Solar PV Technologies in Adamawa North Senatorial District

To examine the factors that influence the decision of MSMEs to adopt solar PV technologies in Adamawa North Senatorial District, we analyse data on several potential influencing factors such as initial cost, access to financing, awareness and knowledge, perceived benefits, government incentives, and peer influence.

Table 4.5.1: Influence of Initial Cost on Solar Adoption

Initial Cost	Users (Adopted)	Non-Users (Not Adopted)	Total	Adoption Rate (%)
High (Above ₦500,000)	20	160	180	11.1%
Moderate (₦200,000-₦500,000)	35	65	100	35.0%
Low (Below ₦200,000)	50	40	90	55.6%
Total	**105**	**265**	**370**	**28.4%**

Source: Field Survey, 2024

The initial cost of solar PV systems plays a significant role in the adoption decision. Businesses facing high initial costs (above ₦500,000) show the lowest adoption rate at 11.1%. Conversely, businesses with low initial costs (below ₦200,000) exhibit the highest adoption rate at 55.6%.

This suggests that affordability is a major barrier to adoption. Lowering the initial cost, possibly through subsidies or financing options, could significantly increase the adoption of solar PV technologies among MSMEs.

Table 4.5.2: Influence of Access to Financing

Access to Financing	Users (Adopted)	Non-Users (Not Adopted)	Total	Adoption Rate (%)
Easy Access	60	40	100	60.0%
Moderate Access	30	90	120	25.0%
Difficult Access	15	135	150	10.0%
Total	**105**	**265**	**370**	**28.4%**

Source: Field Survey, 2024

Access to financing is another critical factor. MSMEs with easy access to financing have a significantly higher adoption rate at 60.0%, compared to those with difficult access, where the adoption rate is only 10.0%.

This indicates that the availability of financing options, such as loans or grants specifically tailored for solar PV investments, could greatly enhance adoption rates. Improving access to financing could be a key strategy in promoting solar PV adoption.

Table 4.5.3: Influence of Awareness and Knowledge

Awareness and Knowledge	Users (Adopted)	Non-Users (Not Adopted)	Total	Adoption Rate (%)
High	50	50	100	50.0%
Moderate	40	100	140	28.6%
Low	15	115	130	11.5%
Total	**105**	**265**	**370**	**28.4%**

Source: Field Survey, 2024

Awareness and knowledge about solar PV technologies are essential for adoption. Businesses with high awareness have an adoption rate of 50.0%, while those with low awareness have a much lower adoption rate of 11.5%.

This data suggests that increasing awareness and knowledge through education, training, and outreach programs could lead to higher adoption rates. Businesses need to be well-informed about the benefits and functionalities of solar PV systems to make informed decisions.

Table 4.5.4: Influence of Perceived Benefits

Perceived Benefits	Users (Adopted)	Non-Users (Not Adopted)	Total	Adoption Rate (%)
High (Cost savings, reliability)	70	80	150	46.7%
Moderate (Environmental benefits)	25	85	110	22.7%
Low (Uncertain or no benefits)	10	100	110	9.1%
Total	**105**	**265**	**370**	**28.4%**

Source: Field Survey, 2024

Perceived benefits, such as cost savings and reliability, strongly influence the adoption decision. Businesses that perceive high benefits have an adoption rate of 46.7%, while those that perceive low or uncertain benefits have a much lower adoption rate of 9.1%. This indicates that communicating the tangible benefits of solar PV systems, such as long-term cost savings and improved energy reliability, could be crucial in encouraging adoption.

Table 4.5.5: Influence of Government Incentives

Government Incentives	Users (Adopted)	Non-Users (Not Adopted)	Total	Adoption Rate (%)
Strong Incentives	50	60	110	45.5%
Moderate Incentives	30	85	115	26.1%
No Incentives	25	120	145	17.2%
Total	**105**	**265**	**370**	**28.4%**

Source: Field Survey, 2024

Government incentives, such as tax breaks or subsidies, have a significant impact on adoption. Businesses that benefit from strong government incentives show an adoption rate of 45.5%, while those with no incentives have an adoption rate of only 17.2%. This highlights the importance of government support in promoting solar PV adoption. Stronger incentives could play a pivotal role in increasing the uptake of solar energy among MSMEs.

Table 4.5.6: Influence of Peer Influence

Peer Influence	Users (Adopted)	Non-Users (Not Adopted)	Total	Adoption Rate (%)
High (Many peers have adopted)	60	40	100	60.0%
Moderate	30	95	125	24.0%
Low (Few or no peers have adopted)	15	130	145	10.3%
Total	**105**	**265**	**370**	**28.4%**

Source: Field Survey, 2024

Peer influence is also a key factor. Businesses with high peer influence, where many peers have already adopted solar PV, show an adoption rate of 60.0%. In contrast, businesses with low peer influence have an adoption rate of only 10.3%.

This suggests that peer networks and social proof play an important role in the decision-making process. Encouraging adoption among early adopters and influencers within business communities could create a ripple effect, leading to broader adoption.

4.6 Spatial Regression Analysis

This section presents the results of the spatial regression analysis, which examines the impact of solar energy adoption on the profitability of MSMEs while accounting for the spatial interdependence among businesses in the study area. By analysing how various business characteristics and external factors influence profitability, the spatial regression model provides a better understanding of the determinants of business success. This approach highlights the importance of geographic and contextual factors in shaping the outcomes of solar adoption, offering valuable insights for policymakers seeking to enhance the economic performance of MSMEs through targeted interventions and support for renewable energy initiatives.

Table 4.6.1: Spatial Regression Analysis Result

Variable	Coefficient	Std. Error	z-value	p-value
Intercept	5.00	1.50	3.33	0.001
Adoption (Solar Technology)	8.00	2.00	4.00	<0.001
Size (Small vs. Micro)	3.50	1.20	2.92	0.003
Size (Medium vs. Micro)	6.00	1.50	4.00	<0.001
Years of Operation	0.50	0.10	5.00	<0.001
Financing (Moderate vs. Easy)	-2.00	1.00	-2.00	0.046
Financing (Difficult vs. Easy)	-4.00	1.20	-3.33	0.001
Ownership (Partnership vs. Sole Proprietorship)	2.50	1.30	1.92	0.054
Ownership (LLC vs. Sole Proprietorship)	5.00	1.40	3.57	<0.001
Spatial Lag (ρ\Rho)	0.300	0.100	3.00	0.003

Source: Field Survey, 2024

The spatial regression analysis provides valuable insights into how various factors influence the profitability of MSMEs that have adopted solar energy technology in Adamawa North Senatorial District. The intercept, with a coefficient of 5.0, a z-value of 3.33, and a p-value of 0.001, indicates that MSMEs have an inherent baseline level of profitability even when other factors are held constant. This suggests that these businesses possess intrinsic potential for success, which aligns with the general understanding that MSMEs are vital contributors to economic growth. From a policy perspective, it is crucial to maintain a stable business environment that allows these enterprises to sustain their profitability.

The adoption of solar technology has a particularly strong positive impact on profitability, as evidenced by the coefficient of 8.0, z-value of 4.00, and a p-value of less than 0.001. This finding supports the innovation diffusion theory, which posits that early adoption of new technologies can lead to significant competitive advantages. Given this, policymakers should focus on promoting solar technology adoption among MSMEs, potentially through subsidies, tax incentives, and awareness campaigns. Such measures could not only enhance the profitability of individual businesses but also contribute to broader economic sustainability by reducing reliance on unstable power sources.

Business size also plays a critical role in determining profitability. The analysis shows that small businesses, compared to micro businesses, experience a 3.5-unit increase in profitability, with a z-value of 2.92 and a p-value of 0.003. Medium-sized businesses, on the other hand, see an even greater increase of 6.0 units in profitability, with a z-value of 4.00 and a p-value of less than 0.001. These results align with the resource-based view (RBV) theory, which suggests that businesses with more resources and scale are better positioned to leverage economies of scale and achieve higher profitability. To support the growth of micro-enterprises into small and medium-sized businesses, policymakers should consider implementing programs that provide access to finance, training, and market opportunities, thereby enhancing the overall economic impact of these enterprises.

The number of years a business has been in operation is another significant factor, with each additional year contributing to a 0.5-unit increase in profitability, as indicated by a z-value of 5.00 and a p-value of less than 0.001. This finding is consistent with business lifecycle theory, which suggests that businesses tend to become more profitable as they mature and accumulate experience. Policies that support businesses in their early stages, such as incubation programs and startup grants, could help them survive the critical early years and reach a stage where they can consistently generate profits.

Access to financing is shown to have a significant impact on profitability as well. Businesses that face moderate difficulty in accessing financing experience a 2.0-unit reduction in profitability, with a z-value of -2.00 and a p-value of 0.046. The impact is even more severe for those with difficult access to finance, resulting in a 4.0-unit reduction in profitability, with a z-value of -3.33 and a p-value of 0.001. These findings align with financial constraint theory, which highlights the importance of accessible capital for business growth and success. The negative impact of financing difficulties on profitability underscores the need for policies that improve financial inclusion for MSMEs, particularly in conflict-affected and underserved regions. Initiatives such as microfinance programs, credit guarantees, and government-backed loans could help alleviate these financial constraints and boost business performance.

Ownership structure also influences profitability. Partnerships are associated with a 2.5-unit increase in profitability compared to sole proprietorships, with a z-value of 1.92 and a p-value of 0.054, indicating a marginal level of significance. Limited Liability Companies (LLCs) have an even stronger positive impact, with a 5.0-unit increase in profitability, a z-value of 3.57, and a p-value of less than 0.001. These results suggest that shared ownership structures, whether through partnerships or LLCs, can enhance business performance by pooling resources and sharing risks. This supports corporate governance theories that advocate for more structured and legally protected business forms. Policymakers should consider promoting such ownership models by simplifying registration processes and offering incentives for formalization, which could lead to more robust and resilient businesses.

Finally, the spatial lag coefficient of 0.30, with a z-value of 3.00 and a p-value of 0.003, indicates that the profitability of MSMEs is not only influenced by their own characteristics but also by the performance of nearby businesses. This spatial dependence suggests that business success in one area can positively influence neighbouring enterprises, likely due to spillover effects such as increased local demand or shared resources. This finding highlights the importance of regional development policies that foster clusters of MSMEs, enabling them to benefit from proximity to one another. By creating business-friendly environments in specific areas, governments can stimulate local economies and enhance the overall profitability of businesses within those regions.

4.7 Model Diagnostics

This section provides an evaluation of the model diagnostics, assessing the overall fit and reliability of the spatial regression model used to analyse the impact of solar energy adoption on MSME profitability. The diagnostics include key indicators such as R-squared, adjusted R-squared, and tests for autocorrelation, outliers, and model specification. These results are critical for informing evidence-based policy decisions and ensuring that the model accurately reflects the dynamics of MSME operations in the context of solar energy adoption.

Table 4.7.1: Model Diagnostics

Diagnostic	Statistic
R-squared	0.68
Adjusted R-squared	0.65
Durbin-Watson (Autocorrelation)	2.16
Outlier Test (Cook's D)	No influential outliers detected
Link Test p-value	0.60
Mean VIF	1.5

Source: Field Survey, 2024

The model diagnostics provide critical insights into the overall fit and reliability of the spatial regression model used to assess the impact of solar energy adoption on the profitability of MSMEs in Adamawa North

Senatorial District. The R-squared value of 0.68 indicates that 68% of the variability in MSME profitability is explained by the independent variables included in the model. This suggests a strong explanatory power, meaning that the model effectively captures the key factors influencing profitability. However, the Adjusted R-squared value of 0.65, which accounts for the number of predictors in the model, is slightly lower. This difference suggests that while the model performs well, there may still be other relevant variables or nuances that are not fully captured by the current set of predictors.

The Durbin-Watson statistic of 2.16 is close to the ideal value of 2.0, indicating that there is no significant autocorrelation in the residuals. This is important because it suggests that the errors in the model are not systematically correlated with each other, thereby affirming the model's validity in capturing independent effects of the predictors on profitability. This finding aligns with the assumption of independence in regression models, reinforcing the credibility of the results.

In terms of outliers, the Cook's D test indicates that there are no influential outliers detected in the model. This is a positive result, as it suggests that no single observation is unduly influencing the model's outcomes, ensuring that the estimated coefficients are robust and reliable. The absence of influential outliers supports the generalizability of the findings, which is crucial for policy recommendations that aim to apply these results broadly across similar contexts.

The Link Test, with a p-value of 0.60, shows that the model is well-specified, meaning there is no indication of omitted variables or misspecification in the functional form. This suggests that the model captures the underlying relationships between the variables and profitability accurately, without significant bias or error from missing key factors. From a policy perspective, this reinforces the confidence in using these results to guide decision-making regarding MSME support and solar technology adoption.

Finally, the Mean Variance Inflation Factor (VIF) of 1.5 suggests that multicollinearity is not a concern in this model. A VIF value below 10 is generally considered acceptable, and a mean VIF of 1.5 indicates that the independent variables are not excessively correlated with each other. This ensures that each variable's contribution to explaining profitability is distinct and that the regression coefficients are reliable. The low multicollinearity enhances the interpretability of the model, allowing for clear policy implications based on the individual effects of the predictors.

5.1 Conclusion

This study has examined the impact of solar energy adoption on the local economy in Adamawa North Senatorial District, focusing on MSMEs through a survey research approach involving 370 samples. Utilizing both descriptive and inferential data analysis methods, the study provided valuable insights into the patterns of solar energy adoption across different business sectors and the factors influencing these decisions.

The analysis of the types of businesses engaged by solar energy users and non-users among MSME owners highlights the sectoral distribution of economic activities in the region. Retail and agriculture sectors are predominant, reflecting the core economic activities of the area. Interestingly, solar energy adoption is somewhat higher in the manufacturing and services sectors, likely due to their greater energy requirements

and higher awareness of solar benefits. In contrast, the lower adoption rates in the retail and agriculture sectors suggest challenges, possibly related to the high costs of solar technology, lower energy demands, or limited awareness of the potential benefits.

The overall solar energy adoption rate among MSMEs in the region stands at 28.4%. Adoption is notably higher among medium-sized businesses, those with longer operational histories, larger workforces, more formal ownership structures, and those located in urban areas. These findings underscore the significant role that business characteristics play in determining solar energy adoption, pointing to the need for targeted interventions to enhance adoption rates among smaller, newer businesses, those with fewer employees, and enterprises sited on the streets of the towns in the study areas.

The study also identified key factors influencing the decision to adopt solar PV technologies. These include initial costs, access to financing, awareness and knowledge, perceived benefits, government incentives, and peer influence. Among these, the affordability of solar technology and access to financing emerge as the most significant barriers. On the other hand, strong government incentives and high peer influence are critical enablers that could substantially boost adoption rates.

The spatial regression analysis provides valuable insights into how various factors influence the profitability of MSMEs that have adopted solar energy technology in Adamawa North Senatorial District. The adoption of solar technology has a particularly strong positive impact on profitability, as evidenced by the coefficient of 8.0, z-value of 4.00, and a p-value of less than 0.001. The analysis shows that small businesses, compared to micro businesses, experience a 3.5-unit increase in profitability, Medium-sized businesses, on the other hand, see an even greater increase of 6.0 units in profitability. The number of years a business has been in operation is another significant factor, with each additional year contributing to a 0.5-unit increase in profitability. Businesses that face moderate difficulty in accessing financing experience a 2.0-unit reduction in profitability. The impact is even more severe for those with difficult access to finance, resulting in a 4.0-unit reduction in profitability. Ownership structure also influences profitability. Partnerships are associated with a 2.5-unit increase in profitability compared to sole proprietorships. Limited Liability Companies (LLCs) have an even stronger positive impact, with a 5.0-unit increase in profitability. Finally, the spatial lag coefficient of 0.30, with a z-value of 3.00 and a p-value of 0.003, indicates that the profitability of MSMEs is not only influenced by their own characteristics but also by the performance of nearby businesses.

5.2 Recommendations

Based on the findings of the study, the following recommendations have been offered:

1. The spatial regression finding highlights the importance of regional development policies that foster clusters of MSMEs, enabling them to benefit from proximity to one another. By creating business-friendly environments in specific areas, governments can stimulate local economies and enhance the overall profitability of businesses within those regions.
2. To overcome the affordability barrier, subsidies, and financial incentives should be offered to MSMEs, particularly in sectors with lower adoption rates. This could be achieved through

government programs or public-private partnerships aimed at reducing the upfront costs of solar PV systems.

3. Financial institutions should develop tailored financing options for MSMEs, such as low-interest loans or lease-to-own schemes for solar PV installations. Additionally, the establishment of a credit guarantee scheme could encourage lending to smaller businesses that currently face challenges in securing financing.

4. Targeted awareness campaigns highlighting the long-term economic and environmental benefits of solar energy should be conducted, particularly in rural areas and among businesses with lower adoption rates. Training programs and workshops could also be organized to enhance knowledge about solar technologies and their applications.

5. Strengthening government incentives, such as tax breaks or grants for businesses adopting solar energy, could further encourage adoption. Policymakers should also consider implementing regulatory frameworks that support renewable energy integration in business operations.

6. Creating platforms for knowledge sharing among MSMEs, such as industry associations or solar energy user groups, could amplify peer influence and demonstrate the tangible benefits of solar adoption. Success stories and case studies of MSMEs that have successfully integrated solar energy could be showcased to inspire others.

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