EFFECT OF SOLAR ENERGY ADOPTION ON THE PERFORMANCE OF SME's IN ADAMAWA NORTHERN SENATORIAL ZONE (A COMPARATIVE STUDY)

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Abstract

This study investigates the effect of solar energy adoption on the performance of Small and Medium Enterprises (SMEs), across the selected markets in the Adamawa Northern Senatorial Zone of Nigeria (A Comparative Studies). Using a mixed-methods approach, the research collected quantitative data from SME operators and analyzed it through spatial regression, ANOVA, and correlation techniques to assess performance impacts, influencing factors, and income outcomes. Findings reveal that the adoption of solar energy serves as a key differentiator for business success among SMEs in the Adamawa Northern Senatorial Zone. The main factor influencing SMEs' adoption of off-grid solar technology is financial constraint particularly the high cost of installation and limited access to financing followed by their specific energy consumption needs. Solar energy contributed to notable improvements in business performance, including increased productivity (38.9%) and reduced operational costs (26.7%), with adopters reporting an average income growth of 15–25% and energy cost savings of 20–30%. Statistical analysis confirms that the type of solar system, year of adoption, and business size are key predictors of performance improvement, while the correlation between solar adoption and business outcomes was especially strong among recent adopters ($\rho = 0.88–0.92$, $p < 0.01$). The study concludes that off-grid solar energy adoption significantly enhances the operational efficiency, financial sustainability, and income of SMEs, particularly when supported by targeted policies, accessible financing, and ongoing awareness campaigns. It recommends integrated policy frameworks, financial interventions, and continued monitoring to optimize solar adoption for broader economic development

Keywords: *Solar Energy, Solar Energy Adoption, Small and Micro Enterprises (SMEs)*

1.1 Background of the Study

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 effect of solar energy adoption on the performance of SME's in stimulating local economic development, considering global trends and experiences.

Adamawa northern 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 (Adeoye & Ekundayo, 2019). 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).

1.2 Research Question

This study entitled evaluating the effect of solar energy adaption on performance of SMEs in Adamawa Northern Senatorial Zone. A comparative study, is designed to provide answers to the following questions.

i. What are the impact of solar energy adoption on the performance of adopters and non-adopters SMEs?
ii. What factor influence the decision of SMEs to adopt off grid solar energy technologies?

1.3 Objectives of the Study

The primary objective of this study; evaluating the effect of solar energy adaption on performance of SMEs in Adamawa Northern Senatorial Zone (A comparative study).

i. To compare the impact of solar energy adoption on the performance of adopters and non-adopters SMEs.
ii. To examine the factors that influence the decision of SMEs to adopt off-grid solar technologies.

1.4 Significance of the study

This study examines the effect of solar energy adoption on the on the performance of MSEs in Adamawa Northern Senatorial Zone (A comparative study) bears significant implications at multiple levels, extending from its global relevance down to its specific impact within Nigeria and, most significantly, in the Adamawa Northern Senatorial Zone.

On a global scale, this research could make a valuable contribution to the ongoing discussion surrounding sustainable energy transitions. At regional level, this research could provide a model that other regions can learn from and replicate. Furthermore, in developing nations where energy access is a critical issue, this study could serve as an instructive example of how solar power can be utilized to address energy poverty and support sustainable development. At the national level, Nigeria has much to gain from the findings of this research as it endeavours to diversify its energy sources and reduce its reliance on fossil fuels. Within the Adamawa North Senatorial Zone itself, the significance of this study is profound. It directly assesses how solar energy adoption influences the performance of SMEs in local economy, providing actionable insights for local government, businesses, and communities to make informed decisions regarding solar energy adoption.

Literature Review and Theoretical Background

2.1 Theoretical Review

They are number of theories that express these phenomena. This includes The Resource-Based Theory, as outlined by Barney (1991) and Wernerfelt (1984); Green Growth Theory, as articulated by Dasgupta (2010) and endorsed by the United Nations Development Programme (UNDP, 2021); The Energy Independence and Security Theory, clarified by Yergin (2006); Technology Diffusion Theory, as introduced by Rogers (1962). This studies were anchored on Random Utility Theory proposed by Lancaster, revolutionized the traditional consumer theory by asserting that utility is derived from the characteristics of a good, rather than from the mere act of consuming the good itself. Therefore, the decision of the MSMEs to subscribe to off-grid solar energy follows the random utility theory (Lancaster, 1991).

2.2 Empirical literature

The review is organized thematically to highlight key dimensions of the literature, including Business-level impacts, Economic growth relationships, Empirical evidence from the EU and Africa and methodological critiques.

2.2.1 Review on Impact of Solar Energy Adoption on SME Performance

This subsection reviews studies that assess the effects of solar energy adoption on small and medium enterprises (SMEs), with a particular focus on profitability, electricity cost reduction, and performance improvements.

The research conducted by Enoch, Owusu-Sekyere, *et al.,* (2024) assessed the impact of solar energy adoption on SME performance in Ghana. Using a mixed-method approach that combined surveys and interviews, the study found that solar energy adoption significantly reduced electricity costs and operational disruptions, enhancing profitability. However, limitations included the reliance on self-reported data and regional focus, which may affect generalizability.

The study on profitability strategies of solar energy businesses in Lagos, Nigeria by Adeoye and Ekundayo (2019) employed a descriptive survey method. Their findings indicated a 20–30% reduction in electricity costs among SMEs using solar systems, leading to increased operational stability and business growth. Nonetheless, the study's limitation lies in its concentration on urban Lagos, which may not reflect rural or northern business environments.

The review of the work of Emmanuel et al. (2021) on solar energy's role in business sustainability in Nigeria used regression analysis to show that solar energy adoption contributes positively to business continuity and income growth. The study also identified that access to financing remains a major barrier. A critique of the study is its cross-sectional nature, which limits the ability to assess long-term impacts.

2.2.2 Renewable Energy and Economic Growth: Global Perspectives

This subsection reviews empirical studies exploring the broader relationship between renewable energy consumption and economic growth, including both developed and developing countries.

The intricate relationship between renewable energy consumption and economic growth is explored in a study by Peijun *et al.* (2023), which analyses data from Next-11 countries using a non-linear ARDL model. Their findings confirm the positive influence of renewable energy consumption on economic growth, along with other drivers like electricity consumption, trade openness, and financial development. The study also highlights asymmetries in the relationship, emphasizing the necessity for policies that balance economic growth with clean energy promotion.

Similarly, Namahoro *et al.* (2021) and Okumus *et al*. (2021) used ARDL and threshold models to study long-run impacts of renewable energy on economic growth in emerging markets and G7 countries. Both studies affirm that renewable energy supports GDP growth, suggesting that increasing investment in renewables can enhance economic development and environmental sustainability.

Daniela *et al.* (2021) provide empirical evidence from the European Union, where renewable energy has been shown to positively influence GDP growth. The study employs regression models using data from Eurostat, and it concludes that countries with a higher share of renewable energy in their energy mix tend to experience stronger economic performance. This supports the call for more aggressive EU-wide renewable energy policies.

2.2.4 Methodological and Contextual Critiques in Renewable Energy Research

This final subsection identifies critical limitations and methodological issues in existing empirical studies, emphasizing the importance of context, model selection, and data quality in shaping conclusions about renewable energy and economic growth.

Chen *et al.* (2020) and Ocal & Aslan (2013) highlight methodological disparities in energy-growth research. While some studies use time-series models like ARDL, others adopt threshold or causality frameworks, each with different assumptions and implications. This diversity makes cross-study comparisons difficult and calls for greater methodological consistency.

Marinaș *et al.* (2018), Stamatios *et al.* (2018), and Songur (2019) critique the oversimplification of energy models. They argue that ignoring variables like innovation, investment, and regulatory frameworks leads to incomplete or misleading conclusions. Their work advocates for multidimensional models that capture the full complexity of energy systems.

Shahbaz *et al*. (2015) and Aslan & Ocal (2016) further stress the need for country-specific models. Their findings show that the relationship between renewable energy and economic growth varies significantly across nations, depending on factors like energy mix, economic structure, and policy context. These studies caution against one-size-fits-all policy prescriptions and advocate for tailored approaches.

2.3 Research Gap

Although global and national studies highlight the opportunities and challenges of solar energy adoption, little empirical research has examined compare its direct impact on SME performance of adopters versus non adopters in the local economic development of Adamawa Northern Senatorial Zone. Addressing this gap is critical to understanding how targeted solar adoption strategies can alleviate energy poverty and stimulate sustainable growth in the region.

Methodology

3.1 Description of the Study Area

Adamawa state is one of the state in the North-East geopolitical zone of Nigeria, bordered by Borno to the northwest, Gombe to the west for 95 km, and Taraba to the southwest for about 366 km, while its eastern border forms part of the national border with Cameroon across the Atlantica Mountains for about 712 km *(*Population *Projection* 2022). Of the 36 states in Nigeria, Adamawa state is the eighth largest in area, but the thirteenth least populous with an estimated population of about 4,902,100, total land area of 39,940 km², a population density of 122.7/km² with an annual population change of 2.7% *(*Population *Projection* 2022). The GDP of the state is estimated at ₦2.66 trillion in 2023. It has the 18th largest economy among the 36 states of Nigeria and the largest in the North-East region. The state is divided into three geopolitical zones as follows Adamawa north, Adamawa central and Adamawa south. Adamawa north comprises of five LGAs, Adamawa central comprises six LGAs and Adamawa south comprises of ten LGAs. The study area for this research is Adamawa northern senatorial zone consisting of Mubi north, Mubi south, Maiha, Michika and Madagali local government areas (LGAs).

3.2 Data collection

The data for this study was sourced from primary and secondary sources from SMEs comprising both adopters and non-adopters of solar energy technology in the study area. Primary data was collected from primary sources using structured questionnaires administered to selected SMEs using an innovative mobile-based tool (Kobocollect) and Secondary data was collected from the Secondary sources online to provide information on the number of SMEs in the state from Small and Micro Enterprises Agency of Nigeia (SMEDAN) website.

Will be drawn from the total population of 24,940 business enterprises registered with CAC in the state as at December 2020 (MSMEs survey report 2021)

3.3 Population and Sample sizes

A total of 360 MSMEs samples was used for the study drawn from the average population of 3,562 enterprises for the five selected LGAs obtained using Taro Yamane's formula.

3.4 Sapling Techniques

Multi-stage sampling approach was used for the study. This involved the selection of five LGAs of Adamawa northern senatorial district in stage one, followed by the selection of markets that have adopted to use off-grid solar energy in the selected LGAs in stage two and finally the random selection of SMEs adopters and non-adopters of off-grid solar energy technology in the markets base on the proposed sample distribution framework.

3.5 Model Specification

Model I: to address objective one is to; assess the impact of adoption on adopters and non-adopters SMEs in Adamawa Northern Senatorial Zone is specify as;

$$PERT_{it} = f(SEA_{it}, ASE_{it}, CSI_{it}, AF_{it}, BP_{it},\ BS_{it},\ GS_{it}) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.1)$$

Transform equation (3.1) into econometric model:

$$PERF_{it} = \beta_0 + \beta_1 SEA_{it} + \beta_2 ASE_{it} + \beta_3 CSL_{it} + \beta_4 AF_{it} + \beta_5 BP_{it} + \beta_6 BS_{it} + \beta_7 GS_{it} + \mu_{it} \ldots \ldots \ldots (3.2)$$

Where; Performance (PER) of SME, Solar Energy Adoption (SEA), Awareness of Solar Energy (ASE), Cost of Solar Installation (CSI), Access to Financing (AF), Perception of Benefits (PB), Business Size (BS), Government Support (GS), The a priori expectation; $\beta_1, \beta_2, \beta_4, \beta_5, \beta_6, \beta_7 > 0$ and $\beta_3 < 0$

Model II: to address objective two is to; examine the factors that influence the decision of SMEs to adopt solar PV technologies specify as;

$$ASPVT_{it} = f(ICPV_{it}, ROI_{it}, AIA_{it}, ENC_{it}, REPS_{it},\ CS_{it}) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (3.3)$$

Transform equation (3.1) into econometric model

$$ASPVT_{it} = \beta_0 + \beta_1 ICPV_{it} + \beta_2 PROI_{it} + \beta_3 AIA_{it} + \beta_4 ENC_{it} + \beta_5 REP_{it} + \mu_t \ldots \ldots \ldots . (3.4)$$

where; Adaptation of Solar PV Technology (ASPVT), Initial Cost of Solar PV (ICPV), Perceived Return on Investment (PROI), Access to information Awareness (AIA), Energy Need and Consumption (ENC) and Reliability of existing Power supply (REPS). The a priori expectation $\beta_2, \beta_{3,} \beta_4 > 0$ and $\beta_1, \beta_5 < 0$

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3.6 Estimation Techniques/Pre and Post-Diagnostic Test

The data was analysed using: Descriptive statistics**,** Correlation analysis**,** Regression analysis**,** Probit estimation and ANOVA (Analysis of Variance).

Result and Discussion

4.1 Introduction

This chapter presents the findings of the study, derived from the analysis of the collected data using parametric and Non-parametric Test statistical methods.

4.2 Result and Interpretation

4.2.1 Comparative Impact of Solar Energy Adoption on Adopters vs. Non-Adopters

Performance Metric	Solar Adopters (Users)	Non-Adopters (Non-Users)
Improved Business Performance	65.6% reported improved performance after adoption.	No improved performance directly linked to solar, as they have not adopted.
Correlation with Performance	Highly significant (ρ = 0.88, p = 0.00) for recent adopters; very strong (ρ = 0.90, p = 0.01) for early adopters.	Not significant (ρ = 0.05, p = 0.34).
Spearman's Rank Correlation	Highly significant (p < 0.01), reinforcing the link between solar use and improved outcomes.	Not statistically significant (ρ = 0.05, p = 0.34).
Specific Benefits	Increased productivity (38.9%) and reduced costs (26.7%).	Continue to face challenges of unreliable grid supply and high alternative energy costs.
Regression Analysis	Strong positive causal link (β = 7.00).	No direct positive effect from solar adoption.

Source: Field survey, 2025

Table 4.1 presents a comparative analysis that highlights the stark differences in business performance between the two groups. For SMEs that have adopted solar energy, a significant majority (65.6%) reported a direct improvement in their business performance. In contrast, the non-adopter group, by definition, did not experience any performance improvements related to solar adoption.

The table further reveals that the relationship between solar adoption and business performance is highly statistically significant for the user group. The correlation analysis for both recent and early adopters showed a strong positive relationship (ρ=0.88 and ρ=0.90 respectively). For non-adopters, however, the correlation was found to be statistically insignificant (ρ=0.05, p=0.34), indicating no measurable relationship between their business activities and solar-related performance indicators.

4.3 Factors that influence the decision of SMES to adopt off-grid Solar Technology

Table 4.3.1 Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Cost of Solar Installation	378	1	5	2.65	1.544
Mode of Financing Solar Energy System	378	1	5	2.46	1.685
Challenges faced in Solar Energy Adoption	378	1	4	2.03	1.210
Access to Financing	378	1	5	2.44	1.655
Business Size	378	1	2	1.04	.202
Energy Need and Consumption	378	1	4	2.61	1.083
What are the main sources of energy for the business?	378	1	4	2.44	1.230
Are you willing to share your solar energy with neighbouring business?	378	1	3	2.56	.625
Cost of Fuel/Electricity Per day	378	1	3	1.38	.533
Valid N (listwise)	378				

Source: *Author's Computation (SPSS 23)*

Table 4.7, the descriptive statistics highlight key insights into solar energy adoption and business energy usage among 378 respondents. The cost of solar installation has a wide range (1 to 5) and an average score of 2.65, indicating diverse perceptions of affordability. Similarly, the mode of financing solar systems and access to financing show significant variability, with mean scores of 2.46 and 2.44, respectively, reflecting challenges in securing financial support. Businesses face moderate challenges in adopting solar energy, with a mean score of 2.03 and less variation (1 to 4**).** Business size is relatively uniform, with most being small-scale (mean of 1.04). Energy needs and consumption vary moderately (mean of 2.61), as do the main energy sources used by businesses (mean of 2.44). Respondents demonstrate some consistency in their willingness to share solar energy**,** with a mean of 2.56 and low variability (1 to 3). Lastly, the cost of fuel or electricity per day has minimal variation (mean of 1.38), suggesting that most businesses incur similar daily energy expenses. These findings underscore diverse experiences and challenges in solar energy adoption, financing, and energy usage across the sample.

Conclusion and Recommendations

5.1 Conclusion

Solar energy adoption among SMEs in the Adamawa Northern Senatorial Zone has shown to be both impactful and economically beneficial. The comparison between solar energy adopters and non-adopters provides conclusive evidence that the adoption of solar energy has a substantial positive impact on SMEs performance. Adopters experience a statistically significant improvement in their business operations, driven primarily by enhanced productivity and reduced costs. This positive effect is completely absent in the non-adopter group. This confirms that solar energy is a critical driver for business success and a viable solution to the power challenges faced by small businesses in the region.

Crucially, solar energy systems offer long-term affordability with low maintenance costs, at ₦1,650–₦3,300 monthly (5%–10% of income)**,** making them financially sustainable for small businesses. When paired with targeted interventions such as subsidies, financing access, and awareness campaigns, the likelihood of adoption increases significantly. These findings collectively affirm that off-grid solar solutions are not only viable for enhancing SME resilience in underserved regions but also serve as a critical strategy for sustainable development in energy-insecure areas.

Policymakers, development partners, and energy providers must therefore prioritize supportive frameworks to accelerate adoption and maximize the socio-economic benefits of solar energy among MSMEs.

5.2 Recommendations

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

1. bridging the performance gap between the two groups and promote widespread economic growth.

To bridge the performance gap, a targeted intervention strategy is recommended. Policymakers should focus on implementing initiatives that specifically address the needs of non-adopters. This could include providing subsidized solar kits or micro-financing options to help them overcome the financial barriers to adoption. Furthermore, targeted educational campaigns that highlight the proven benefits of solar, as demonstrated by the success stories of current adopters, can serve to convince non-users to make the transition.

2. Promote Financial Incentives and Accessible Financing Options

The findings reveal a positive income impact (15%–25%) and significant cost savings (20%–30%), but many SMEs still face barriers to initial capital. Financial barriers can be addressed with tailored instruments such as micro-loans, lease-to-own schemes, and flexible credit products developed in partnership with financial institutions and solar providers. Example Financial Regulators and Banks should develop SME-focused green energy credit products, such as launching a "Green SME Credit Scheme**"** with ≤7% interest loans, flexible collateral, and 12–24 months' repayment terms. Also, local authorities should partner with cooperatives to pilot community-based lease-to-own or pay-as-you-go (PAYG) solar schemes for microenterprises.

3. Target High-Impact Businesses for Solar Investment

Spatial and regression analysis shows larger, multi-branch SMEs recorded higher cost savings ($\rho = 0.490$, $p < 0.000$)**.** Policymakers and donors should prioritize scalable, high-energy SMEs for strategic solar investment, such as establishing a "High-Impact Solar Accelerator**"** to fund solar installations for energy-intensive SMEs. Local government should use business census data to identify and target commercial hubs or energy-vulnerable clusters for solar infrastructure rollout.

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