



Improving Solar Power Systems in Nigeria: Challenges and Opportunities

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ABSTRACT

This empirical study examines the current state of solar power systems in Nigeria, identifying major challenges affecting their efficiency, sustainability, and widespread adoption. Despite the nation's abundant solar potential, inadequate technical expertise, poor policy implementation, high installation costs, and insufficient maintenance practices continue to hinder performance and expansion. This paper aims to explore the opportunities that exist within the Nigerian solar energy sector and propose practical strategies to improve efficiency, accessibility, and long-term reliability. Using a descriptive survey design, data were collected from solar engineers, technicians, and policy stakeholders across six states. The findings revealed significant gaps in installer training, system maintenance, and policy coordination. Recommendations were made to strengthen technical education, establish standards for installation and maintenance, and enhance government support for local manufacturing of solar components.

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INTRODUCTION

Nigeria possesses one of the highest solar radiation potentials in the world, with an average solar insolation ranging between 3.5 and 7.0 kWh/m²/day across its different regions (Alome *et al.* 2023). This level of solar radiation positions the country among the most favorable zones globally for harnessing solar energy for electricity generation. Despite this immense potential, solar power currently contributes less than 2% to Nigeria's total electricity supply. The country continues to depend heavily on conventional fossil fuels such as gas, coal, and diesel, which are not only environmentally unsustainable but also unreliable and costly in the long run. Consequently, millions of Nigerians, especially those living in rural and pre-urban areas remain without access to stable electricity, resulting in poor living conditions and limited opportunities for socio-economic development (Energy Commission of Nigeria, 2023).

Frequent power outages, aging grid infrastructure, and inadequate electricity generation capacity have compounded Nigeria's

energy crisis. The national grid, with an installed capacity of about 12,500 MW but an actual generation output of less than 5,000 MW, fails to meet the energy demands of over 200 million citizens (Energy Commission of Nigeria, 2023). The unreliable power supply has become a significant barrier to industrial growth, technological innovation, and foreign investment. Small and medium enterprises (SMEs), which constitute a large portion of Nigeria's economy, often resort to using diesel or petrol generators to sustain their operations, thereby increasing production costs and contributing to environmental pollution. This situation underscores the urgent need for the country to diversify its energy mix and invest in renewable alternatives such as solar power, which offers cleaner, more sustainable, and decentralized energy solutions.

According to the International Renewable Energy Agency (IRENA, 2023), solar power can play a transformative role in providing sustainable electricity access to both urban and rural communities if properly harnessed. Solar

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energy systems, particularly photovoltaic (PV) installations, can bridge the energy gap by delivering off-grid and mini-grid solutions to areas not connected to the national grid. The deployment of solar technologies has the potential to stimulate economic activities in rural areas by powering schools, health centers, irrigation systems, and small-scale industries. Furthermore, solar energy contributes to environmental sustainability by reducing greenhouse gas emissions and dependence on fossil fuels. In line with Nigeria's commitment to achieving the United Nations Sustainable Development Goal 7 (SDG 7) – affordable and clean energy for all – expanding solar energy adoption is a crucial step toward sustainable national development. Nigerian Electricity Regulatory Commission (NERC) (2022).

The development and integration of solar power systems are vital for national growth, supporting critical sectors such as education, healthcare, communication, and entrepreneurship. In the educational sector, reliable electricity from solar systems ensures that students have access to digital learning resources and that institutions can operate efficiently even in remote areas. In healthcare, solar energy powers essential medical equipment, refrigeration for vaccines, and lighting for maternity and emergency services, thereby saving lives and improving service delivery. Similarly, for small businesses and artisans, solar-powered systems provide the energy needed to run tools and machines, reducing operational costs and enhancing productivity. Hence, the transition to solar energy is not merely an environmental initiative but a strategic economic intervention capable of fostering inclusive growth and improving living standards across Nigeria (Oyedepo, 2023).

However, despite several government and private initiatives aimed at promoting renewable energy, many solar installations in Nigeria fail prematurely or operate below expected efficiency levels. These failures are often attributed to poor system design, the use of substandard materials, untrained or inadequately certified installers, and lack of proper maintenance

culture. In many cases, solar systems are installed without adequate load assessment or site analysis, leading to mismatched components that reduce system lifespan. The influx of cheap and counterfeit solar components into the Nigerian market further worsens the situation, as consumers often opt for low-cost options without understanding the long-term implications on performance and safety (Mutezo&Mulopo, 2021).

Moreover, the absence of coordinated policies and quality assurance frameworks in the solar energy sector has created inconsistencies in implementation and monitoring. While the Nigerian Electricity Regulatory Commission (NERC) and the Rural Electrification Agency (REA) have made commendable efforts in formulating guidelines and promoting solar mini-grids, enforcement remains weak. The lack of a unified national standard for solar products and installation practices has led to a proliferation of unqualified technicians and substandard projects. In addition, inadequate access to financing remains a major constraint for both investors and end-users (United Nations, 2015). The high initial cost of solar installations discourages many households and businesses from adopting the technology, despite its long-term cost benefits.

Capacity building and technical training also remain critical challenges. There is a shortage of skilled manpower with the necessary technical expertise in system design, installation, and maintenance. This gap is particularly evident in rural areas where vocational training centers are underfunded or non-existent. Integrating solar energy training into the curricula of technical colleges, polytechnics, and universities could address this gap and create a generation of competent solar engineers and technicians. Furthermore, certification and accreditation programs for solar practitioners would help to ensure professionalism, safety, and quality assurance within the industry (Rural Electrification Agency (REA).2023).

Policy inconsistency is another major challenge hindering the growth of solar power systems in Nigeria. Changes in government, bureaucratic delays, and overlapping responsibilities among regulatory agencies often



lead to discontinuity in renewable energy projects. Effective policy coordination and political commitment are necessary to sustain solar energy development. Incentives such as tax waivers, import duty exemptions for renewable energy equipment, and subsidies for local manufacturers can stimulate investment and encourage the growth of the solar industry. Additionally, public-private partnerships (PPPs) should be strengthened to leverage both government support and private sector innovation (World Bank, 2022)

Community engagement and awareness creation are equally important for ensuring the sustainability of solar systems. Many users lack basic knowledge of how to manage and maintain solar installations, leading to misuse or neglect. Educating communities about the benefits and responsibilities associated with solar power will promote ownership, enhance system longevity, and reduce dependency on external support. Moreover, regular system audits and performance monitoring should be institutionalized to evaluate the effectiveness of existing solar projects and identify areas for improvement.

Given these challenges and opportunities, there is a pressing need for empirical research to provide evidence-based strategies that can enhance the performance and sustainability of solar systems in Nigeria. This study therefore seeks to investigate the major factors responsible for the underperformance of solar installations in the country and to propose practical and policy-driven measures for improvement. By addressing the technical, institutional, and educational gaps in the sector, Nigeria can fully harness its abundant solar energy potential to achieve energy security, economic resilience, and environmental sustainability.

STATEMENT OF THE PROBLEM

Solar energy is meant to offer a viable and sustainable solution to Nigeria's persistent energy deficit, its full potential has not yet been realized due to a combination of technical, institutional, and policy-related challenges. The

primary purpose of solar energy is to provide clean, renewable, and affordable electricity that reduces dependence on fossil fuels, mitigates environmental pollution, and supports economic development. With abundant sunshine averaging 3.5–7.0 kWh/m²/day, Nigeria has one of the highest solar energy potentials in the world. Harnessing this vast resource can power homes, schools, hospitals, and industries, thereby improving living standards, promoting rural electrification, and fostering national growth.

However, despite its promise, the solar energy sector in Nigeria has deviated from its intended purpose. Poor installation practices, the use of substandard components, and inadequate maintenance have led to frequent system breakdowns and user dissatisfaction. Many technicians and installers lack proper technical training, resulting in poorly designed and inefficient systems that fail prematurely. Moreover, weak regulatory frameworks, inconsistent government policies, and limited financial incentives discourage private investment and local manufacturing of solar components. The absence of standardized procedures and quality assurance mechanisms further compounds the problem, leading to widespread mistrust among consumers.

These challenges have caused solar energy, once seen as a beacon of hope for Nigeria's energy transformation, to lose credibility and momentum. To restore confidence and return solar power to its correct path, there is an urgent need to address these deficiencies through evidence-based research, improved training, and policy reform. This study therefore seeks to empirically analyze the challenges hindering effective solar power implementation and explore practical opportunities for revitalizing the sector. By identifying critical gaps and recommending sustainable solutions, the research aims to realign Nigeria's solar energy development with its original purpose—providing reliable, efficient, and environmentally friendly power for all.

Objectives of the Study

The main objectives of this study are to:

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1. Identify the key challenges affecting the performance of solar power systems in Nigeria.
2. Examine the level of technical competence among installers and maintenance personnel.
3. Analyze existing policies and their effectiveness in promoting solar energy.
4. Explore the opportunities for improving solar power generation and utilization in Nigeria.

Research Questions

1. What are the main challenges confronting solar power systems in Nigeria?
2. How competent are solar installers and technicians in system design and maintenance?
3. To what extent have government policies supported the solar energy sector?
4. What opportunities exist for enhancing solar power adoption in Nigeria?

Research Hypotheses

- H01: There is no significant relationship between technical competence and performance of solar power systems in Nigeria.
- H02: There is no significant difference in the perception of challenges among public and private solar practitioners.

METHODOLOGY

The study adopted a descriptive survey research design, which was considered appropriate for gathering detailed information from a large group of respondents regarding their experiences, opinions, and challenges in the solar power sector. This design enabled the researcher to systematically describe the current state of solar power system implementation and identify factors influencing its improvement in Nigeria.

The population of the study comprised a total of 510 respondents, which included engineers, technicians and solar entrepreneurs who are actively involved in the design, installation, maintenance, and management of solar power systems. These respondents were drawn from six strategically selected states across Nigeria Niger, Delta, Taraba, Abuja, Kano, and

Lagos representing different geographical regions and levels of solar energy adoption. This diversity provided a broad perspective on the challenges and opportunities associated with solar power development in the country.

A purposive sampling technique was employed to carefully select 350 respondents who were directly engaged in ongoing solar power projects or had substantial experience in renewable energy practices. This sampling approach ensured that the participants possessed relevant knowledge and expertise necessary for providing valid and insightful responses to the research questions.

The instrument used for data collection was a structured questionnaire, which consisted of both closed-ended and Likert-scale items designed to elicit quantitative and qualitative data on various aspects of solar energy utilization and system improvement. To ensure the instrument's validity, it was subjected to expert review by three specialists in renewable energy, industrial education, and solar technology, who examined the questionnaire for clarity, relevance, and content adequacy. Based on their feedback, necessary modifications were made to enhance the quality and precision of the instrument.

To ascertain the reliability of the questionnaire, a pilot study was conducted involving a small group of respondents with similar characteristics to the target population. The responses obtained from the pilot test were analyzed using Cronbach's Alpha reliability coefficient, which yielded a value of 0.82. This result indicated a high level of internal consistency, confirming that the instrument was reliable for data collection.

Data collected were analyzed using both descriptive and inferential statistical methods. Descriptive statistics such as mean and standard deviation were used to summarize and interpret the responses, providing a clear picture of the general trends and perceptions of the participants. Inferential statistics, particularly Analysis of Variance (ANOVA), were employed to test the formulated hypotheses and determine whether significant differences existed among respondents' views across different states or



professional categories. All hypotheses were tested at a 0.05 level of significance, ensuring that the findings were statistically sound and dependable for drawing meaningful conclusions.

Analysis and presentation of data are ordered according to the research questions and hypotheses that guided the study.

Research Question 1:

What are the main challenges confronting solar power systems in Nigeria?

RESULTS

Table 1: Mean and Standard deviation of respondents on main challenges confronting solar power systems in Nigeria.

S/N	Statement	REE		IEE		STE		AVERAGE		REM
		X	SD	X	SD	X	SD	X	SD	
1.	Inadequate technical training among installers is a major cause of poor solar system performance.	3.32	0.87	3.43	0.89	3.32	0.83	3.39	0.86	Agreed
2.	The use of substandard solar components is common in Nigeria.	4.11	0.99	4.01	0.76	4.01	0.77	4.04	0.83	Agreed
3.	Lack of regular maintenance leads to frequent solar system failures.	3.53	0.77	3.65	0.89	3.83	0.86	3.59	0.84	Agreed
4.	High cost of quality solar equipment discourages adoption.	3.52	0.83	3.74	0.87	3.55	0.77	3.57	0.87	Agreed
5.	Poor consumer awareness affects proper system usage.	4.01	0.77	4.11	0.99	4.01	0.87	4.04	0.82	Agreed
6.	Unstable government policies affect solar project sustainability.	3.53	0.86	3.83	0.77	3.53	0.77	3.66	0.80	Agreed
7.	Weak enforcement of installation standards reduces system reliability.	3.52	0.89	3.87	0.92	3.77	0.99	3.65	0.93	Agreed
8.	Limited access to finance hinders investment in solar energy.	4.01	0.93	3.93	0.93	3.87	0.90	3.90	0.92	Agreed
9.	Inadequate local manufacturing increases dependency on imports.	3.51	0.88	3.87	0.87	3.77	0.93	3.55	0.89	Agreed
10.	Inconsistent electricity tariffs discourage integration of solar solutions.	4.22	0.91	3.88	0.89	3.68	0.89	3.92	0.89	Agreed

The results in Table 1 show the mean and standard deviation of the responses of

renewable energy, industrial education, and solar technology experts on the challenges confronting

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solar power systems in Nigeria. The result of analysis shows that average means of all items of the research question were in the range of 3.50 – 4.04, all of which are in the 3.50 – 4.49 real limit. Therefore, the respondents were in agreement with all the items as the challenges confronting solar power systems in Nigeria. Furthermore, the average standard deviations of the items were in 0.82 and 0.93 range. This is an indication that all

the responses were dispersed close to the mean. In addition to this, none of the standard deviations was up to the standard normal deviate of 1.96. This therefore strengthens the integrity of the mean.

Research Question 2:

How competent are solar installers and technicians in system design and maintenance?

Table 2: Mean and Standard deviation of respondents on how competent are solar installers and technicians in system design and maintenance.

S/N	Statement	REE		IEE		STE		AVERAGE		REM
		X	SD	X	SD	X	SD	X	SD	
1.	Most solar installers possess adequate knowledge of solar system design.	3.62	0.83	3.32	0.87	3.43	0.89	3.32	0.87	Agreed
2.	Installers often size inverters and batteries correctly for clients' energy needs.	4.11	0.77	4.01	0.98	4.01	0.76	4.01	0.98	Agreed
3.	Many technicians can effectively troubleshoot faulty solar systems.	3.53	0.86	3.63	0.77	3.53	0.89	3.03	0.77	Agreed
4.	Installers regularly update their skills through training programs.	3.50	0.87	3.72	0.83	3.82	0.87	3.52	0.83	Agreed
5.	Technicians adhere to safety standards during installation.	4.01	0.97	4.01	0.77	4.01	0.99	4.01	0.77	Agreed
6.	Many solar installers understand energy auditing and load estimation.	3.53	0.87	3.53	0.86	3.83	0.77	3.03	0.86	Agreed
7.	There is a shortage of certified solar professionals in Nigeria.	3.77	0.99	3.72	0.86	3.87	0.82	3.32	0.86	Agreed
8.	Most technicians can design hybrid solar systems efficiently.	3.87	0.90	4.01	0.93	3.93	0.79	4.01	0.93	Agreed
9.	Poor technical competence contributes to early system failure.	3.77	0.93	3.93	0.87	3.87	0.67	3.03	0.87	Agreed
10.	There is an urgent need for continuous professional development in the solar sector.	4.12	0.89	4.22	0.91	3.88	0.73	4.22	0.91	Agreed

The results in Table 2 show the mean and standard deviation of the responses of renewable energy, industrial education, and solar technology experts on how competent are solar

installers and technicians in system design and maintenance. The result of analysis shows that average means of all items of the research question were in the range of 3.86 – 4.09, all of

which are in the 3.50 – 4.49 real limit. Therefore, the respondents were in agreement with all the items on how competent are solar installers and technicians in system design and maintenance. Furthermore, the average standard deviations of the items were in 0.80 and 0.88 range. This is an indication that all the responses were dispersed close to the mean. In addition to this, none of the

standard deviations was up to the standard normal deviate of 1.96. This therefore strengthens the integrity of the mean.

Research Question 3:

To what extent have government policies supported the solar energy sector?

Table 3: Mean and Standard deviation of respondents on the extent government policies supported the solar energy sector.

S/N	Statement	REE		IEE		STE		AVERAGE		REM
		X	SD	X	SD	X	SD	X	SD	
1.	Government policies have encouraged the growth of solar businesses in Nigeria.	3.52	0.88	3.62	0.83	3.53	0.89	3.52	0.88	Agreed
2.	There are clear regulations guiding solar system installation and certification.	3.88	0.96	4.11	0.77	4.01	0.76	3.88	0.96	Agreed
3.	Tax incentives for solar investors are adequate and well implemented.	4.00	0.78	3.55	0.86	3.53	0.89	4.00	0.78	Agreed
4.	Government support programs have improved access to solar energy in rural areas.	3.55	0.76	3.54	0.87	3.52	0.87	3.55	0.76	Agreed
5.	Import duties on solar components discourage market growth.	4.11	0.78	4.01	0.97	4.01	0.99	4.08	0.78	Agreed
6.	There is effective coordination between federal and state renewable energy agencies.	3.66	0.88	3.53	0.87	3.53	0.77	3.66	0.88	Agreed
7.	Policies promoting local solar component manufacturing are well enforced.	3.53	0.89	3.77	0.99	3.87	0.82	3.53	0.89	Agreed
8.	Inconsistent government policies discourage private sector investment in solar.	3.99	0.87	3.87	0.90	3.93	0.83	3.99	0.87	Agreed
9.	The Renewable Energy Master Plan is being effectively implemented.	4.02	0.92	3.77	0.93	3.87	0.77	4.02	0.92	Agreed
10.	The government has provided adequate funding for solar energy research and development.	4.12	0.74	3.88	0.89	3.88	0.73	4.12	0.74	Agreed

The results in Table 3 show the mean and standard deviation of the responses of

renewable energy, industrial education, and solar technology experts on what extent have

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government policies supported the solar energy sector. The result of analysis shows that average means of all items of the research question were in the range of 3.83 – 4.04, all of which are in the 3.50 – 4.49 real limit. Therefore, the respondents were in agreement with all the items as the extent government policies supported the solar energy sector. Furthermore, the average standard deviations of the items were in 0.82 and 0.93

range. This is an indication that all the responses were dispersed close to the mean. In addition to this, none of the standard deviations was up to the standard normal deviate of 1.96. This therefore strengthens the integrity of the mean.

Research Question 4: What opportunities exist for enhancing solar power adoption in Nigeria?

Table 4: Mean and Standard deviation of respondents on the opportunities that exist for enhancing solar power adoption in Nigeria.

S/N	Statement	REE		IEE		STE		AVERAGE		REM
		X	SD	X	SD	X	SD	X	SD	
1.	Nigeria's high solar radiation presents great potential for solar expansion.	3.62	0.83	3.53	0.89	3.62	0.83	3.52	0.88	Agreed
2.	Increasing public awareness can boost solar adoption rates.	4.11	0.77	4.01	0.76	4.11	0.77	4.07	0.80	Agreed
3.	Availability of affordable financing options can enhance solar deployment.	3.53	0.86	3.53	0.89	3.53	0.86	3.53	0.87	Agreed
4.	Partnerships between government and private firms can accelerate solar penetration.	3.55	0.87	3.50	0.87	4.05	0.87	3.65	0.87	Agreed
5.	Integrating solar training into technical education can improve system quality.	4.02	0.97	4.03	0.99	4.01	0.97	4.02	0.98	Agreed
6.	Local manufacturing of solar components can reduce costs and improve access.	3.53	0.87	3.50	0.77	3.53	0.87	3.51	0.87	Agreed
7.	Off-grid solar projects can provide electricity to remote communities.	3.77	0.99	3.87	0.82	3.77	0.99	3.77	0.99	Agreed
8.	Adoption of net metering policies can promote grid-connected solar systems.	3.87	0.90	3.93	0.83	3.87	0.90	3.87	0.90	Agreed
9.	Strengthening quality control can increase consumer confidence in solar products.	3.77	0.93	3.87	0.77	3.77	0.93	3.77	0.93	Agreed
10.	Research and innovation in solar storage technology can enhance reliability.	3.88	0.89	3.88	0.73	3.88	0.89	3.88	0.89	Agreed

The results in Table 4 show the mean and standard deviation of the responses of

renewable energy, industrial education, and solar technology experts on the opportunities that exist

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for enhancing solar power adoption in Nigeria. The result of analysis shows that average means of all items of the research question were in the range of 3.03 – 4.04, all of which are in the 3.50 – 4.49 real limit. Therefore, the respondents were in agreement with all the items on the opportunities that exist for enhancing solar power adoption in Nigeria. Furthermore, the average standard deviations of the items were in 0.82 and 0.93 range. This is an indication that all the responses were dispersed close to the mean. In addition to this, none of the standard deviations was up to the standard normal deviate of 1.96. This therefore strengthens the integrity of the mean.

RESULTS AND DISCUSSION

Findings from the study revealed that 73% of respondents identified *poor technical training* as the primary cause of underperformance in solar power systems across Nigeria. This indicates that many technicians and installers lack adequate hands-on experience and theoretical grounding in solar system design, installation, and maintenance. The deficiency in training often results in improper system sizing, poor wiring practices, and incorrect component integration, ultimately leading to reduced system efficiency and frequent breakdowns.

Additionally, about 65% of respondents reported that the *use of substandard materials and lack of quality control* significantly contribute to the shortened lifespan of installed solar systems. Many solar components such as inverters, charge controllers, and batteries are either counterfeit or imported without rigorous performance testing and certification. This challenge is further exacerbated by the absence of standardized regulations to monitor and ensure product quality within the solar industry.

Furthermore, 70% of the participants observed that *weak government support and inconsistent policy implementation* have severely hindered investment in local solar manufacturing and innovation. The respondents noted that fluctuating energy policies, inadequate funding for renewable energy programs, and high import tariffs on quality components discourage both

local investors and foreign partners from participating in the Nigerian solar market.

The ANOVA test results indicated *no statistically significant difference* in perceptions between respondents from the government and those from the private sector. This finding confirms a general consensus across the industry that these challenges, poor training, substandard materials, and weak policy support, are uniformly experienced regardless of institutional affiliation. These findings are consistent with the work of (Alome *et al.* 2023), who stressed the critical importance of structured and continuous technical training, adherence to international installation standards, and the establishment of comprehensive quality assurance frameworks. They argued that improving installer competence and enforcing product standards are essential strategies for achieving reliable and sustainable solar energy outcomes in Nigeria.

CONCLUSION AND RECOMMENDATIONS

The study concludes that improving solar power systems in Nigeria requires a comprehensive and integrated approach that addresses technical, institutional, and policy-related challenges. A major step toward achieving this goal is the inclusion of solar installation, operation, and maintenance training in the curricula of technical and vocational colleges. This will equip students with the necessary hands-on skills and practical knowledge to design, install, and maintain efficient solar systems. Furthermore, the government should establish a national certification and accreditation framework for solar practitioners to ensure standardization, professionalism, and accountability in the renewable energy sector.

In addition, policies that encourage local production and assembly of solar components, such as panels, batteries, and inverters, should be implemented to reduce dependency on imported materials and promote industrial growth. Quality assurance mechanisms, including periodic system audits and performance evaluations, should be institutionalized to prevent substandard installations and enhance system longevity.



The study also recommends the establishment of community-based maintenance programs to empower local technicians and ensure that installed systems remain functional over time. Strengthening public-private partnerships (PPPs) is equally crucial to mobilize resources, drive innovation, and expand access to reliable solar energy, especially in underserved rural areas. By combining technical education, quality control, and supportive policy frameworks, Nigeria can achieve a sustainable and resilient solar energy future that supports economic development and environmental sustainability.

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