

Renewable Energy in Nigeria: A Comprehensive Examination of the Viability of Solar Energy in Nigeria.

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Abstract—Energy is an essential factor in all sectors of any nation's economy. This paper investigates the need for the maximization of renewable energy and its potential for sustainable development, emphasizing the key role solar power can play in addressing Nigeria's energy shortfalls. Solar energy, which is obtained from the sun, is the world's most abundant and cheapest source of energy available from nature. The discourse incorporates socio-economic considerations, technological barriers, and the need for effective and friendly governmental policies to instigate solar power initiatives. Key propositions include developing Nigerian-made photovoltaic (PV) panels, patenting innovations, human capacity building, and fostering PV technology clusters. The discourse concludes by highlighting the transformative potential of solar power, envisaging a sustainable future for Nigeria through renewable energy.

Index Terms—Renewable Energy, Solar Energy, Nigeria, Sustainable Development, Solar Photovoltaic

I. INTRODUCTION

Energy is a fundamental driver of economic development and social well-being across the globe. Just as it is globally, in Nigeria, energy plays an important role in the socioeconomic dynamics, impacting various sectors such as transportation, living standards, job creation, education, agriculture, and healthcare [1]. The availability of reliable and affordable energy is therefore essential for sustaining these sectors and fostering overall national growth.

Despite its importance, Nigeria faces a major challenge in its energy sector. The National Grid, which primarily serves the country, is continuously affected by limited coverage and inadequate infrastructure. As a result, a large portion of the population remains without access to reliable

electricity. Even in areas where it is available, the supply is often inconsistent and insufficient to meet the growing demand bring about very common cases of load shedding [2], [3]. This occurrence has resulted in widespread reliance on alternative power sources, such as petrol-powered generators, which are expensive to procure/maintain and have proven to be environmentally unsustainable [4].

The growing population in Nigeria, coupled with increasing urbanization and industrialization, is expected to skyrocket the demand for electricity. This necessitates urgent measures to explore sustainable and environmentally friendly alternative sources of energy. Renewable energy, particularly solar energy, presents a workable option for addressing Nigeria's current and predicted energy challenges. Solar energy, being abundant and geographically well-distributed across the country, offers a practical solution to meet the energy demands of both urban and rural areas [5].

Nigeria's geographical location on a high solar radiation belt, combined with growth in solar photovoltaic (PV) technology, positions the country to harness solar energy efficiently. The potential benefits of solar energy in Nigeria include but are not limited to, a reduced dependence on non-renewable energy sources, decreased greenhouse gas emissions, and enhanced energy security [6]. Additionally, solar energy can contribute to economic growth by creating jobs and stimulating the development of local industries to compete with global industries of same sector.

However, the adoption of solar energy in Nigeria is not without challenges. Affordability, lack of awareness, technological barriers, and bad government policies

are major setbacks that need to be properly addressed [7].

Renewable energy, defined as energy derived from natural resources that are replenished on a human timescale, including sources such as sunlight, wind, water (hydropower), geothermal heat, biomass, and biofuels [8]. Among the various kinds of renewable energy, solar energy stands out due to its abundance, accessibility, and potential to meet a significant part of the world's energy needs [9]. Solar energy, harnessed through technologies such as solar photovoltaic (PV) and solar thermal systems, has gained global recognition as a sustainable and environmentally friendly source of energy [10].

Nigeria, with its rich endowment of renewable energy resources, is well-positioned to benefit from the global paradigm shift towards cleaner energy sources. The country receives substantial solar radiation all year long, making solar energy one of the most promising renewable energy options in her drive to having a more reliable energy sector.

Studies have posited that Nigeria experiences nearly 290 days of sunlight annually, with average solar insolation ranging from 4.0 kWh/m² per day in the southern coastal areas to 7.0 kWh/m² per day in the northern regions [11]. This geographic advantage, together with the increasing innovations in the development of solar PV technology, provides a strong layer for the advancement of solar energy in Nigeria.

The accessibility and affordability of solar energy makes it an attractive option for all classes of Nigeria's fast-growing population. Unlike other renewable energy sources that may require significant infrastructure investments, solar energy can be harnessed using decentralized systems such as rooftop solar panels, making it more accessible to a wider population [12].

Additionally, the technological advancements in solar PV have significantly improved the efficiency and cost-effectiveness of solar energy systems. Innovations in materials, manufacturing processes, and energy storage technologies have reduced the cost of solar PV panels, making them more competitive with conventional energy sources [13]. Furthermore, the modular nature of solar PV systems allows for scalability, enabling their use in various forms, from

small-scale residential installations to large-scale solar farms.

Despite these benefits, the adoption of solar energy in Nigeria faces several challenges. The initial cost of solar energy systems, although decreasing, remains a barrier for many individuals and businesses, particularly in a country where a significant portion of the population lives below the poverty line [14]. Furthermore, the lack of awareness about the immeasurable benefits and capabilities of solar energy has hindered its extensive adoption. Many people still perceive solar energy as only suitable for small-scale applications, such as powering bulbs or small appliances, without recognizing its potential as a reliable source for broader energy generation.

Government, by extension her policies and support are also a key player in the development of solar energy. While there have been some efforts to promote renewable energy in Nigeria, the absence of a clear and consistent policy framework has limited the growth of the solar energy sector [15]. To fully actualize its potential, there is a need for targeted enabling policies that incentivize investment in solar technology, support research and development, and create an enabling environment for the adoption of solar energy.

It is clear that solar energy holds significant potential for addressing Nigeria's energy challenges. However, to fully harness this potential, it is essential to address the economic, technological, and policy-related barriers that currently impede the growth of the solar energy sector.

This paper therefore examines the feasibility of deepening the exploration solar energy in Nigeria, exploring the socio-economic, geographical, and technological factors that influence its adoption. The study also discusses the potential benefits of solar energy and provides recommendations for overcoming the challenges to its extensive adoption.

II. METHODOLOGY

This study employed a systematic approach to evaluate the viability of solar energy in Nigeria, focusing on data collection, data analysis, feasibility assessment, and stakeholder consultations.

The data collection process began with an extensive review of secondary data sources to gather relevant information on solar insolation levels across Nigeria.

Data such as solar radiation, sunshine duration, and geographical distribution were obtained from credible sources, including the Solar Electric Light Fund (SELF), the Nigerian Meteorological Agency, and international databases such as the World Bank's Global Solar Atlas. The data covered various regions across Nigeria, providing a comprehensive overview of the country's current solar energy potential.

In addition to solar insolation data, economic data related to the cost of solar photovoltaic (PV) systems, including installation, maintenance, and operational costs, was also collected. These data were sourced from government reports, industry publications, and previous academic studies. The goal was to assess the financial implications of adopting solar energy on a large scale in Nigeria.

The collected data were subjected to a detailed analysis to determine the feasibility and potential impact of solar energy in different regions of Nigeria. Geographic Information System (GIS) tools were used to map the solar insolation data across the country, highlighting areas with the highest potential for solar energy generation. Statistical analysis was performed to calculate average solar insolation levels, identifying the most suitable regions for large scale solar energy projects. Economic analysis was also conducted to compare and contrast the cost-effectiveness of solar energy systems with conventional energy sources, such as fossil fuels. This involved calculating the Levelized Cost of Electricity (LCOE) for solar PV systems, which considers the total lifetime costs divided by the energy produced. Sensitivity analysis was performed to assess how changes in key variables, such as solar panel prices and maintenance costs, could affect the overall feasibility of solar energy projects.

The feasibility assessment aimed at evaluating the practicality of implementing solar energy solutions in Nigeria's specific socio-economic and infrastructural divide. This involved assessing the availability of solar energy technology, the readiness of the market, and the existing infrastructure for large scale energy distribution.

The study considered various factors, such as the availability of local expertise, the capacity for local manufacturing of solar components, and the regulatory environment. The assessment also explored potential barriers to solar energy adoption, including financial, technical, and policy-related challenges. For instance,

the study examined the affordability of solar energy systems for both residential and industrial users, taking into account Nigeria's income distribution and economic conditions. The assessment further considered the impact of government policies, such as tariffs on imported solar equipment and incentives for renewable energy projects.

To complement the quantitative analysis, qualitative insights were gathered through consultations with key stakeholders in Nigeria's energy sector. These stakeholders included policymakers from the Ministry of Power, industry experts from solar energy companies, researchers from academic institutions, and representatives from non-governmental organizations (NGOs) involved in renewable energy advocacy.

The consultations were conducted through structured interviews and focus group discussions. Stakeholders were asked to provide their perspectives on the opportunities and challenges associated with solar energy in Nigeria. They also shared insights on current initiatives, future plans, and the role of government policies in shaping the renewable energy landscape. The information gathered from these consultations was invaluable in understanding the practical realities of implementing solar energy projects in Nigeria. Stakeholders highlighted critical issues such as the need for public awareness campaigns, the importance of capacity building, and the possibility of securing interest of private-sector within and outside the country involvement in scaling up solar energy adoption.

The Methodology is presented in Table I

Stage	Details
Data Collection	Sources: Solar Electric Light Fund (SELF), Nigerian Meteorological Agency, World Bank Global Solar Atlas. Data Types: Solar insolation levels, economic data on solar PV systems, installation, maintenance costs.
Data Analysis	Tools Used: Geographic Information System (GIS) for mapping, Statistical analysis for averages, Levelized Cost of Electricity (LCOE) calculations. Comparative Analysis: Solar energy vs. conventional energy (fossil fuels).
Feasibility Assessment	Focus: Availability of technology, market readiness, existing energy infrastructure, policy environment.

	Challenges Identified: Financial barriers, technical challenges, policy gaps.
Stakeholder Consultation	Participants: Policymakers, industry experts, researchers, NGO representatives. Method: Structured interviews focus group discussions. Insights Gathered: Challenges, opportunities, policy recommendations.

The results of this study reveal a promising landscape for the adoption of solar energy in Nigeria, supported by robust data analysis and stakeholder insights. The findings are categorized into several key areas: solar insolation levels, economic viability, environmental impact, and challenges to solar energy adoption.

The analysis of solar insolation data across Nigeria indicates a high potential for solar energy generation throughout the country. The study found that Nigeria benefits from an average of nearly 290 days of sunlight per year. Solar insolation levels, which measure the amount of solar radiation received per square meter, range from 4.0 kWh/m² per day in the southern coastal regions to 7.0 kWh/m² per day in the northern regions. These figures proved that the northern part of Nigeria is particularly favorable for large-scale solar energy projects due to its higher solar insolation levels.

The mapping of solar radiation data using Geographic Information System (GIS) tools showed that most regions in Nigeria receive sufficient sunlight all through the year to make solar energy a viable option for both residential and industrial applications. This geographic advantage positions Nigeria as a prime candidate for significant investment in renewable energy.

The economic analysis conducted in this study indicates the cost-effectiveness of solar energy systems compared to conventional fossil fuel-based energy sources. The Levelized Cost of Electricity (LCOE) for solar photovoltaic (PV) systems was found to be competitive, especially when considering the declining costs of solar panels and the minimal maintenance required for solar installations.

The study also revealed that, while the initial capital costs of solar installations are higher than those of conventional energy systems, the long-term benefits outweigh these initial expenses. Solar energy systems have low operational costs and require minimal maintenance, leading to significant savings over time. The economic benefits are particularly evident in regions where electricity supply from the national grid

has proved unreliable or non-existent, as solar energy can provide a stable and consistent power supply.

The analysis showed that a quality investment in solar energy has the potential reduce Nigeria's dependency on costly fuel-powered generators, which are widely used across the country to supplement the unreliable access to electricity from the national grid. By reducing the need for fuel imports and associated costs, solar energy adoption could conserve foreign exchange and contribute to Nigeria's economic stability.

The environmental analysis indicates that solar energy offers substantial benefits in terms of reducing greenhouse gas emissions and mitigating environmental pollution. Transitioning to solar energy from fossil fuel-based electricity generation can also significantly lower Nigeria's carbon footprint. Solar energy, as a clean and renewable energy source, produces no direct emissions during operation, thereby helping to improve air quality and reduce the health risks associated with air pollution. The replacement of petrol-powered generators, which are known for their high emissions of carbon dioxide (CO₂) and other pollutants, with solar power would lead to a considerable reduction in the environmental impact of Nigeria's energy sector. Added to this; by decreasing reliance on coal and oil for electricity generation, Nigeria can also play a role in reducing global greenhouse gas emissions and combating climate change.

Despite the clear advantages of solar energy, there exist several challenges that need to be addressed to facilitate widespread adoption in Nigeria.

One of the primary challenges is the high upfront cost of solar energy systems, which remains a significant barrier for many households and businesses, especially in a country where a large portion of the population lives below the poverty line. The study also found that public awareness of solar energy's benefits is limited, with many Nigerians perceiving solar power as an expensive and unreliable energy source suitable only for small-scale applications. This misconception hinders the broader adoption of solar energy technologies.

In addition, the analysis revealed gaps in government policy and support for renewable energy. The absence of comprehensive and enabling policies for solar energy investment, along with a lack of clear and

consistent regulatory frameworks, has slowed the growth of the solar energy sector in Nigeria. The study also pointed out the limited infrastructure to support large-scale solar energy projects, such as a lack of grid integration for distributed solar generation and inadequate local manufacturing capacity for solar components.

The study's findings also indicate that the feasibility and potential impact of solar energy vary across different regions in Nigeria. While northern regions with higher solar insolation levels are more suitable for large-scale solar farms, southern regions, despite having slightly lower solar radiation, still present significant opportunities for residential and commercial scale for solar installations. The regional analysis suggests that tailored approaches are necessary to maximize the benefits of solar energy across Nigeria.

III. CONCLUSION

In conclusion, this paper emphasizes the significance of overcoming challenges and capitalizing on opportunities in advancing solar power in Nigeria. The identified barriers, such as affordability, lack of awareness, and inadequate policies, must be addressed through a multifaceted approach. The proposed strategies, including the development of indigenous photovoltaic (PV) panels and capacity building, offer a roadmap for realizing the renewable energy potential. Embracing solar power would not only attempt to address Nigeria's long time energy shortfall but also promote economic growth, technological innovation, and job creation.

As Nigeria aspires to become solidify its claim as an economic giant in Africa, the shift towards renewable energy would mark a critical step towards sustainable development, environmental stewardship, and global competitiveness.

REFERENCES

- [1] S.O. Oyedepo, "Energy and Sustainable Development in Nigeria: The Way Forward," *Energy Sustainability and Society*, vol. 2, 2012.
- [2] F.G. Akinboro, L. Adejumobi, and V. Makinde, "Solar Energy Installation in Nigeria: Observations, Prospect, Problems, and Solution," *Transnational Journal of Science and Technology*, vol. 2, no. 4, pp. 73-84, 2012.
- [3] D. Games, "Nigeria's Power Deficit Holds Back Growth," *New African Magazine*, 2020. [Online]. Available: <https://newafricanmagazine.com/24704/>
- [4] C. Odetunde, "Rural Electrification and the Energy Sufficiency," 2008. [Online]. Available: <http://www.nigeriavillagesquare.com/articles/chris-odetunde/rural-electrification>.
- [5] G. Tsilingiridis, G. Martinopoulos, and N. Kyriakis, "Life Cycle Environmental Impact of a Thermosyphonic Domestic Solar Hot Water System in Comparison with Electrical and Gas Water Heating," *Renewable Energy*, vol. 29, pp. 1277-1288, 2004.
- [6] J. Freling and J. Lahl, "Renewable Energy Technology: Optimizing Energy Sources for the Development of Millennium Project Villages," *Washington DC, USA: Solar Electric Light Fund (SELF)*, 2005.
- [7] Y. Akinpelu, "Analysis: Nigeria's solar wealth can fix costly electricity problem," *Premium Times*, 2021. [Online]. Available: <https://www.premiumtimesng.com/news/headlines/469043->
- [8] Solar Energy International, "Energy Facts," 2011. [Online]. Available: <http://www.solarenergy.org/resources/energyfacts.html>.
- [9] K. Uduma and T. Arciszewski, "Sustainable Energy Development: The Key to a Stable Nigeria," *Sustainability*, vol. 2, pp. 1558-1570, 2010.
- [10] M.D. Michael and E.E. Esther, "Exploring the Economic and Environmental Benefits of Solar Energy Generation in Developing Countries: The Nigerian Perspective," *Journal of Energy Technologies and Policy*, vol. 3, no. 6, pp. 23-31, 2013.
- [11] A.B. Ajayi, "A Survey of Solar Energy Power Systems," *8th International Conference on Environment and Electrical Engineering*, 2009. [Online]. Available: <http://opus.kobv.de/btu/volltexte/2009/771/pdf/EEEIC2009.pdf>
- [12] R. Freling and J. Lahl, "Optimizing Energy Sources for the Development of Millennium Project Villages," *Solar Electric Light Fund*, 2005.
- [13] G. Tsilingiridis, G. Martinopoulos, and N. Kyriakis, "Life Cycle Environmental Impact of a Thermosyphonic Domestic Solar Hot Water System in Comparison with Electrical and Gas

- Water Heating," *Renewable Energy*, vol. 29, pp. 1277-1288, 2004.
- [14] M.S. Adaramola, "Viability of Grid-Connected Solar PV Energy System in Jos, Nigeria," *International Journal of Electrical Power & Energy Systems*, vol. 61, pp. 64-69, 2014.
- [15] O. Ikponmwoosa, "Solar Energy Potential and its Development for Sustainable Energy Generation in Nigeria: A Road Map to Achieving this Feat," *Renewable Energy Research*, 2014. [Online]. Available: <https://www.researchgate.net/publication/262349356>.