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Assessment of Off-Grid Power Plants in Nigeria: Location, Capacity, Performance and Current Status

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The power sector in Nigeria still struggles with significant electricity challenges resulting from the unavailability of power supply and the unreliability of the conventional national grid. The total installed capacity of off-grid plants in Nigeria is approximately a meagre 52 MW, with a combination of 67 operational mini-grids and solar home systems across the country impacting only about one million households and around five million residents out of Nigeria's population of over 200 million people. It has been reported that both urban and rural areas suffer the impact of power shortages and frequent blackouts. The unreliability of power supply in Nigeria has been identified as a significant problem affecting educational institutions in terms of productive learning, student residency and institutional operations, and also the overall operation of healthcare facilities as it limits access to quality healthcare services. The study examines the presence and potential of off-grid power solutions in Nigeria which present a more reliable approach to supplying electricity to users, as a deliberate response to the multiple and complex challenges in the Nigerian power systems to identify the present location, installed capacity, operational performance, and current

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status of off-grid power plants in Nigeria. The Geographic Information System and statistical approaches were employed. It was discovered that off-grid solutions are beginning to spread across the country on different scales. However, most rural areas in Nigeria still do not have access to electricity supply. The study encourages decentralized power generation in the country and emphasizes the need for the federal government through the Rural Electrification Agency (REA) to consider investing in off-grid solutions, particularly in the rural areas for socio-economic benefits.

Keywords: Off-grid power; Nigeria; energy access; data analysis; installed capacity; performance; Geographic Information System (GIS).

1. INTRODUCTION

The national grid is a system that interconnects all the electrical generation stations, transmission substations, and distribution substations [1]. In Nigeria, the national grid plays a principal role in the power sector. However, its unreliability and incapacity to meet the ever-increasing demand for electricity has always resulted in frequent widespread blackouts, which hurts both rural and urban regions. The unreliability of the on-grid power system has motivated the birth of an off-grid alternative approach to accessing electricity to communities.

Off-grid power plants in Nigeria play a crucial role in addressing the country's energy challenges by providing decentralized and reliable electricity to remote areas [2]. As Nigeria strives for sustainable development, off-grid solutions have become progressively important and a strategic response to multifaceted challenges and the pursuit of overarching goals.

The term "off-grid" in its simplest form refers to energy systems that are not connected to the central grid infrastructure. These systems can include standalone solar power systems, wind turbines, microgrids, and other localised power generation and distribution solutions.

In Nigeria, the exploration of off-grid power plants has become increasingly essential in addressing energy challenges. According to Ogunbiyi [2], as Nigeria seeks sustainable solutions, off-grid systems offer a promising avenue for decentralized and reliable electricity access, particularly in remote areas where traditional grid infrastructure is limited.

The off-grid power solution aims to enhance access to reliable electricity, especially in remote regions where traditional grid penetration is challenging. This initiative is motivated by a set of objectives encompassing economic development, social empowerment, and environmental sustainability. However, this also comes with obstacles such as financial barriers, infrastructural constrictions, and the like.

For many years, Nigeria has been faced with the continuous struggle for power supply to her citizens from the national grid which is an On-grid power system. Even though several homes, companies, and other commercial establishments are connected to the national grid, there are still the majority of people who do not have access to the national grid because of geographical locations or lack of finance to service their electricity bills.

According to the World Economic Forum [3] and Moss [4], Nigeria faces several challenges with its on-grid power plants, contributing to issues in the country's overall power sector; some of these challenges are:

- Inadequate and unsatisfactory power generation creates gaps between electricity demand and supply with the effect of regular power shortages.
- Unreliable power supply resulting in frequent outages and fluctuations with significant negative effects on businesses and household operations and the impact on economic productivity.
- Lack of network Infrastructure refers to the transmission and distribution networks that are incapable of meeting the growing energy demand and of course, causing transmission losses, inadequacies, and contributing to a less reliable electricity supply.
- The interruption of natural gas supply for gas-powered plants in Nigeria as a result of pipeline vandalization has negatively affected the on-grid power generation and also the stability of the grid.
- Electricity theft and non-payment of bills have been identified as major challenges that affect the financial state of the

distribution companies and also impact the company revenue. Revenue losses make it difficult for utilities to invest in improvements, affecting the quality and reliability of power supply.

- Poor maintenance culture contributes to the deterioration of power infrastructure and reduces efficiency and the lifespan of power plants. This also contributes greatly to the frequency of downtime and of course, higher maintenance costs, and reduces the reliability of the power generation system.
- Inconsistent guidelines, regulatory uncertainties, and political interference contribute to a challenging business environment for power sector stakeholders. Lack of long-term planning, regulatory stability, and clear policies hinder private sector investment and overall sector development.

Off-grid power solutions, including decentralized renewables, microgrids, energy storage, and community engagement, offer viable alternatives to address these challenges. Executing off-grid solutions can meaningfully contribute to closing the energy access gap, especially in remote and underserved areas. As Nigeria engages in a diversified and robust energy landscape, a mixture of on-grid and off-grid solutions can guarantee a more reliable, sustainable, and all-encompassing power supply for Nigeria's energy needs.

Off-grid power solutions play a vital role in this endeavour as they address energy needs in remote environments, reduce the environmental impact that comes with on-grid power generation, encourage economic growth, promote educational opportunities, and improve healthcare services.

2. LITERATURE REVIEW

2.1 The Lack of Power Supply

The foundation of any societal development and improved quality of life of any nation depends largely on the availability of and accessibility of electricity supply. According to a 2014 International Energy Agency Report [5], over 1.3 billion people worldwide lacked reliable access to power. Most of these individuals reside in rural regions. The lack of power, particularly in rural areas, has made it difficult to achieve several of the Millennium Development Goals (MDGs).

According to Emodi [6], access to reliable and affordable electricity supply is an indispensable necessity for economic growth, improved living standards, and overall development in any country. Nigeria, as the most populous nation in Africa, has long struggled with insufficient power supply from the national grid.

Even though a significant portion of Nigeria's population is connected to the national utility grid, there are still residents, particularly in rural areas, who face challenges in establishing connections due to financial constraints and/or environmental factors. As a result, Emodi [6] reported that for most residences, electricity is generated from gasoline or diesel-powered generators, which can be noisy and have the effect of increasing greenhouse gas emissions which hurts the environment. Besides other environmental problems associated with the use of petrol and diesel generators, it is quite expensive to run them. With the emergence of off-grid system solutions, many residents in Nigeria are making attempts and adopt the off-grid system owing to the economic implication of running generators.

Nigeria's energy issues need to be resolved via off-grid power alternatives to the traditional grid system. Off-grid solutions have the potential to significantly reduce emissions from fuel generators and diesel, which are often used in Nigeria, and to accelerate economic growth, particularly in rural areas. By converting to mini-grids and solar electricity, Nigeria may strengthen its rural economy, reduce rural-urban migration, and encourage cottage companies [7,8]. With the help of the Rural Electrification Agency (REA), more underserved and rural Nigerian clusters will have access to electricity through its Off-Grid Electrification Strategy. The Power Sector Recovery Programme (PSRP), of which this plan is a part, intends to enhance customer satisfaction, reduce losses, increase transparency, improve service delivery, and restore the financial viability of Nigeria's power sector [2]. When everything is taken into account, off-grid energy solutions offer a practical way to increase agricultural productivity, reduce poverty, enhance food security, and promote economic growth in Nigeria. By focusing on off-grid power options and other renewable energy sources like solar electricity, Nigeria may address its energy problems, empower smallholder farmers, and foster long-term economic growth [8].

Nigeria's sustainable growth has made off-grid alternatives more crucial for several reasons:

Market potential: With its sizable economy, expanding population, and a sizable section of the populace without access to the national grid, Nigeria offers a sizable off-grid potential in Africa. Nigerian households and businesses stand to gain significantly from the development of off-grid alternatives such as mini-grids and solar home systems, which have the potential to save billions of dollars yearly [2].

Cost-Effectiveness: In remote locations where expanding the national grid might be prohibitively expensive, off-grid solar systems provide a financially viable option for producing power. Off-grid solutions reduce energy costs by enabling homes and companies to produce their electricity.

Reliability: Off-grid solar systems offer a dependable supply of electricity that is essential for locations with unreliable grid electricity since they are not susceptible to the same power outages and blackouts as the national grid. This dependability guarantees the continuous provision of vital services such as healthcare and education.

Sustainability: Because off-grid systems run on renewable energy sources like the sun, they are less dependent on fossil fuels and emit fewer damaging greenhouse gases. For Nigeria, whose energy industry is mostly dependent on fossil fuels, this move towards renewable energy is essential. Economic Growth: By providing mechanised farming methods to smallholder farmers, off-grid solutions boost productivity, raise incomes, decrease poverty, improve food security, and open up new agricultural markets. All of these factors collectively lead to economic growth. Off-grid solutions offer an environmentally friendly way for Nigeria to tackle its energy challenges, boost economic growth, improve its livelihoods, and achieve long-term sustainable development goals by addressing the challenges associated with electricity in the agricultural sector [8].

It is necessary to evaluate some aspects of off-grid power plants in Nigeria, such as the regulatory environment, market potential, business case assessment, site selection procedure, financing possibilities, and sustainability problems. Renewable energy is impacted by rules set out by the Nigerian Electricity Regulatory Commission (NERC), including feed-in tariffs and power purchase agreements [9]. Nigeria, with its sizable population and restricted grid access, offers a substantial off-grid possibility [2]. The business case review underscores the off-grid solutions' financial feasibility in Nigeria, stressing the need to carefully select the site and collaborate with organisations such as the World Bank to get funding [2]. The regulatory landscape, market potential, business case, site selection procedure, and funding sources must all be evaluated for off-grid power plant development in Nigeria to be effective. Long-term success also depends on tackling sustainability-related issues, such as appropriate planning and giving grid power generation priority when it is practical [10].

The goal of the assessment is to address major issues and offer solutions to increase the availability and accessibility of off-grid power supply in underserved and rural areas. Off-grid solar systems - which run mostly on solar energy- are emphasised as an economical and effective way to electrify rural places [11]. The spread of off-grid electrification depends on policy support, which includes a long-term electrification plan and reliable information for stakeholders [12]. Off-grid renewable energy solutions are viewed as revolutionary because they give rural people all over the world access to safe, cheap electricity, therefore enhancing their social and economic standing [13]. According to Babalola et al. [14], mini-grids—which are characterised as independent power systems or networked distributed energy resources—are essential for fostering micro and small businesses and helping rural communities realise their full economic potential. To guarantee a cheap and dependable supply of power in underserved areas, the assessment highlights the significance of integrating communities in the mini-grid design process, creating norms and regulations by governments, and striking a balance between the interests of investors, communities, and governments.

A key consideration in the examination of off-grid power plants is geography. Factors including solar irradiance, wind speeds, height, topography, humidity, air pressure, land quality, and closeness to transmission lines are crucial to take into account when deciding where to put renewable energy projects [15-17]. Areas like Chile's Atacama Desert, which has extended hours of sunshine, high elevation, little cloud cover, and little pollution, are perfect for solar installations [15]. Conversely, because of unimpeded winds and greater capacity potential,

wind turbine installations benefit from high wind speeds in places like Argentina's southern tip or offshore sites [15]. Furthermore, for the efficient design and execution of off-grid power supply systems, variables such as load statistics, demographic information, geographic data, land use patterns, and climatic conditions are taken into account [18]. To maximise the sustainability and financial viability of off-grid power facilities, geographic considerations are essential.

It is anticipated that the investigation of Nigeria's off-grid power plants will produce several suggestions. These suggestions may be to prioritise the production of grid electricity over off-grid options, stress the need for careful planning before starting any off-grid initiatives, and concentrate on sustainable energy solutions that use renewable resources like solar, biomass, and small hydro. Moreover, the research can recommend making investments in renewable infrastructure, stabilising the grid to lessen financial losses brought on by unstable power supplies, and promoting policy coordination within the energy sector to improve governance [10]. The relevance of these suggestions in influencing Nigeria's energy landscape is underscored by the possibility that renewables might account for a sizable fraction of the country's energy consumption by 2030 and beyond [19].

2.2 Demand and Supply of Electricity in Nigeria

According to a UN Department of Economic and Social Affairs research published in the Vanguard Nigeria Newspaper in [20], it is anticipated that by 2050, Nigeria would have the third-highest population in the world. Expert estimates indicate that if Nigeria's population isn't supported by social amenities and proportionate jobs, it will have increased by 4% by 2040.

The Vanguard Newspaper [21] reports that power generation increased to 1,811.3 megawatts in January 2019 under the administration of His Excellency Mohammed Buhari (GCFR), and that the transmission company of Nigeria (TCN) transmitted 127,157.7 megawatts, down from 125,346.4 megawatts in December 2018. But this was thought to be insufficient to meet Nigeria's energy needs as a growing country. This demonstrates that Nigeria has a very inadequate supply of energy, leading to a significant disparity between supply and demand.

Adesola [22] stated that unreliability and power outages were major challenges faced in the 2006 Nigerian population and housing census at a seminar on data collection processing held in Tanzania. In a similar vein, the Central Bank of Nigeria stated in its 4th quarter statistics bulletin (2012) that one of the main obstacles to the expansion and development of Nigerian businesses is an inadequate power supply. Due to this shortage, company owners are unable to manage their companies effectively, which has led to an increase in the cost of living.

In a publication made by Doris [23], it states that Nigeria is the most populous country in Africa. It highlights that Nigeria's population increased to over two hundred million in the year 2020. With this amount, a high volume of electricity generation is required to meet the electricity demand of the individual Nigerians. In the same year, however, power generated amounted to about 35.7 thousand gigawatt hours. Having generated this power, it is considered insufficient in comparison to the level of electricity demand, which surpassed 29 terawatt hours in the same year. It was recommended to encourage more electricity generation investment in the country to close out the gap in the demand-supply of electricity in the country.

2.3 Access to Electricity

Any nation's ability to expand socioeconomically quickly and sustainably depends on its ability to provide enough infrastructure services, particularly electricity. However, the Nigerian power industry has always been characterised by insufficient and inconsistent access to energy services [24]. Not everyone in Nigeria can acquire electricity for use. Doris [25], reported that only about 55% of Nigerians could access electricity. It was reported in the Vanguard Nigeria Newspaper [21], that 30% of the population had electricity and the absence of electricity was more prevalent in rural areas while 90% was recorded in the urban population.

Furthermore, in the same year, it was reported that the northeast and northwest zones recorded high levels of lack of electricity. Besides, it was noted that as of 2022, the electricity demand in Nigeria has risen to over 32 terawatt hours. Following the Statista’s prediction, the

household, and industries' average electric power consumption per capita will rise on an annual basis. The report added that by 2023, consumption per Nigerian household will rise to approximately 165 kilowatt hours (kWh) and grow up to 166 kilowatt hours by 2025.

2.4 Solar PV Hybrid Energy Systems

Studies have shown that the subject of producing renewable off-grid power in rural areas is not new. Okoye [26] conducted a study on the viability of solar photovoltaic (PV) systems for rural electrification in sub-Saharan Africa, comparing the cost of electricity produced by PV to that of a standalone diesel generator in a Nigerian rural area. The author concluded that a solar mini-grid was a more cost-effective method of producing electricity after observing a USD 0.22/kWh difference in the utilisation of the two energy systems. Olatomiwa et al. [27] conducted a feasibility study in which they assessed the financial effects of implementing a solar photovoltaic/diesel/battery hybrid energy system throughout Nigeria's six geopolitical zones. A diesel generator was used in this study as a backup energy source and was only intended to run briefly. Researchers have looked at the viability of operating a small solar grid system that is solely powered by renewable energy sources. Bertheau [28] provided a case study examining the application of solar, wind, and battery technologies for the electricity of a Philippine island. Similar to this, Krishan and Suhag [29] assessed the utilisation of three hybrid setups for an Indian hamlet lacking an electrical supply and came to the conclusion that a wind/solar/battery system was the most economical option for the area. Nevertheless, the Arthurs underscored the location-dependent nature of wind technology in mini-grid systems applications.

It is obvious that the centralized power generation and distribution system has not been adequate in meeting the growing energy demands of the nation's burgeoning population and it is therefore the aim of this review study to comprehensively analyze off-grid power plants in Nigeria, breaking down their presence by geopolitical locations, and assessing the installed capacities and operational status and performances in each state and recommend more availability and accessibility of off-grid power supply to the rural and underserved regions.

3. MATERIALS AND METHODS

This section details the approach employed in our study by providing a comprehensive account of our investigational approach. We seek to provide valuable insights into the practical challenges and opportunities of off-grid power systems and also serve as a foundation for future advancements in the field.

3.1 Data Collection

Primary and secondary sources were used to provide the data for this research. Interviews with industry experts constituted the primary data. Secondary data was sourced from a review of official reports from relevant government agencies, energy reports, and academic literature. The study covers a specified timeframe and includes a representative sample of off-grid plants across different regions in Nigeria. The key variables considered include plant location, installed capacity, operational efficiency, and current status.

3.2 Data Types

The collected data comprises both quantitative and qualitative data. Quantitative data includes numerical values such as installed capacity. Qualitative data encompasses insights from interviews and on-site observations, providing a nuanced understanding of the plants' operational challenges and successes.

3.3 Data Analysis

The quantitative data are subjected to statistical analysis using tools such as descriptive statistics. Geographic Information System (GIS) mapping techniques are employed to visualize the spatial distribution of off-grid plants. Qualitative data undergoes thematic analysis to identify recurring patterns, challenges, and success factors.

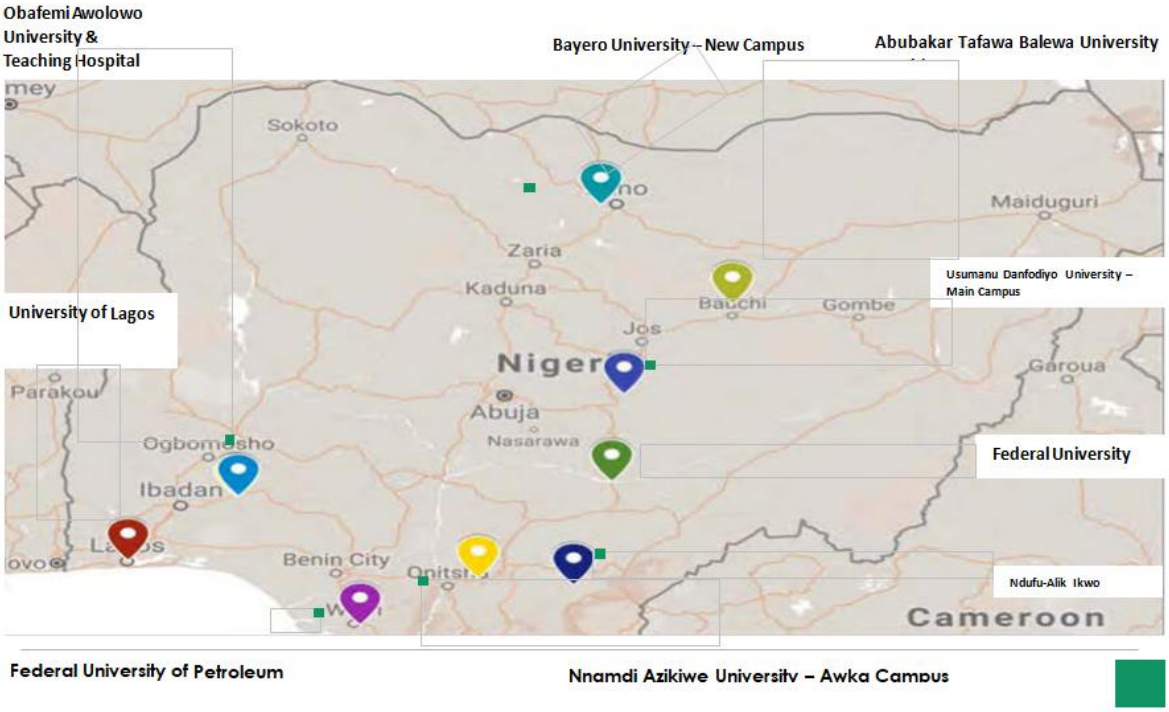
Table 1. Renewable and data-driven electrification solutions in Nigeria

	North-Central	North-West	North-East	South-West	South -East	South - South
2020						
GRID	32	18	28	23	16	26
SOLAR STREET LIGHT(SSL)	6	2	3	1	2	4
SOLAR MINI GRID (SMG)	8	10	6	7	6	5
SOLAR HOME SYSTEMS (SHS)	60	73	61	36	47	20
TOTAL	**106**	**103**	**98**	**67**	**71**	**55**
2021						
GRID	46	32	24	24	38	28
SOLAR STREET LIGHT(SSL)	1	1	-	1	2	2
SOLAR MINI GRID (SMG)	1	1	-	-	5	1
SOLAR HOME SYSTEMS (SHS)	31	51	27	24	31	32
TOTAL	**79**	**85**	**51**	**59**	**76**	**63**
2022						
GRID	37	25	32	13	28	16
SOLAR STREET LIGHT(SSL)	53	63	48	56	33	45
SOLAR MINI GRID (SMG)	4	4	1	2	7	9
SOLAR HOME SYSTEMS (SHS)	4	4	1	1	2	2
TOTAL	**98**	**96**	**82**	**72**	**70**	**72**

Source: Rural Electrification Agency Impact Report

4. RESULTS AND DISCUSSION

The data gathered and analyzed are hereby presented in this section. They include both quantitative and qualitative data.



Picture 1. Spatial distribution of off-grid plants

4.1 Some Off-Grid Plants in Nigeria

The data gathered and analyzed shows that off-grid power plants are spread across the country, serving both urban and rural areas on different scales.

For this study, the authors focus on some selected off-grid plants across Nigeria for quick identification and analysis.

1. **Off-Grid Plant at the Federal University of Agriculture, Makurdi:** An off-grid power plant has been identified on the campus of the Federal University of Agriculture, Makurdi in Benue State, in the North Central part of Nigeria. The plant runs on a Solar PV-hybrid technology and has a capacity of 8.25MW. The plant is currently active and performing optimally. The plant was constructed by the Rural Electrification Agency (REA) under the Energizing Education Program (EEP) of the federal government in July 2018 and was completed in August 2020 and commissioned in October 2020.
2. **Off-Grid Plant at the Bayero University in Kano:** Located on the campus of Bayero University in Kano, Kano State, in the Northern part of Nigeria is a Solar PV-hybrid off-grid plant with a capacity of 7.1MW. The plant consists of 10,680 solar panels installed on approximately 2 hectares of land space. The plant is actively running and performing efficiently. The project which lasted from February 2018 to September 2019 was executed by the Rural Electrification Agency (REA) under the Energizing Education Program (EEP) of the federal government.
3. **Off-Grid Plant at Alex Ekwueme Federal University:** The off-grid power plant at Alex Ekwueme Federal University located in Ndufu Alike-Ikwo, Ebonyi state, in the Southeastern region of Nigeria, signifies a sustainable energy solution in the institution as it aims to enhance energy availability and reliability and redirect attention from the national grid. It has a capacity of 2.8 megawatts (MW), with a solar PV component consisting of 3,500 solar panels. The plant is actively in

operation with high efficiency in performance. The project was executed by the Rural Electrification Agency (REA) on behalf of the federal government.

4. **Off-Grid Plant at Usman Dam in Bwari, Abuja:** The water treatment plant rated 1.52MW employs an inventive off-grid approach, designed to operate off the conventional power grid. The facility derives its source from renewable energy for its operations, ensuring sustainable practices and resilience.

The off-grid solar PV plant is strategically located at the Usman Dam in Bwari, Abuja. Where limited access to the main power grid has been identified as a challenge. The plant is presently up and performing efficiently.

5. **Off-Grid Plant at Nigeria Breweries (NB) Plc:** The off-grid solar PV plant at Nigeria Breweries (NB) Plc is located in the city of Ibadan, Oyo State, in the Southwestern part of Nigeria serving as a major facility for sustainable energy and operational independence. The plant has a capacity of 0.663MW with 1,680 solar panels. The plant construction which started in March 2019 became actively operational in November 2020 and it is performing excellently.
6. **Off-Grid Plant at Federal University of Petroleum, Effurun:** The 1.35MW Solar Hybrid off-grid power plant located at the Federal University of Petroleum, Effurun (FUPRE), Delta State; serves as a decentralized energy source in supporting the university's day-to-day operations. The plant is still actively playing essential roles in meeting the electricity needs of the facilities within the university.
7. **Off-Grid Plant at Nnamdi Azikiwe University:** Nnamdi Azikiwe University off-grid plant is a 2.5MW solar PV power plant, well located within the Nnamdi Azikiwe University campus in Anambra state, Nigeria. The project is designed to enhance energy generation in the institution. The project commenced in 2018 and was completed in 2019 and is currently active and performing well up to date.
8. **Off-Grid Plant at Usumanu Danfodiyo University:** The project was designed to effectively serve the staff members and students of Usumanu Danfodiyo University in Sokoto state with safe, clean, and reliable energy. The 2.0MW Solar (PV) hybrid is currently and adequately powering the University campus and the library including streetlights on the campus.

Some off-grid power plants in Nigeria have been identified in the study and the summary of the plants showing their geographical location, installed capacity, operational performance and current status are tabulated in Table 2.

4.2 The Presence of Solar Photovoltaic (PV) Solutions in Nigeria

Solar photovoltaic (PV) technology is progressively taking hold of the energy market and gaining popularity in Nigeria as a sustainable energy solution. Considering the solar PV technology deriving its energy from the sunlight, it is evidence that it has the advantages of minimizing greenhouse gas emissions and less dependency on fossil fuels. The technology is particularly beneficial in remote areas as Solar PV requires less maintenance, hence reduced cost. While reliance on the national grid has proven to be unreliable, the use of solar PV solutions ensures energy security.

The study has gathered that the drastic growth in solar PV installation in Nigeria is a response to the demand for clean energy solutions.

Data from the installation of different Solar (PV) solutions has been taken as cited in Table 1 and analyzed for three years across the six geo-political locations in Nigeria and are presented in Figs. 1, 2 and 3.

The assessment of off-grid initiatives across different geo-political locations in Nigeria indicates a booming Grid business in the country and it uncovers thousands of opportunities for potential off-grid projects.

The report presented in Fig. 1 shows that the off-grid plant is present in all geo-political locations with the highest number situated in the North-Central and the least in South-East locations respectively.

While Solar Street Lights and Solar Mini Grid are relatively distributed across different locations, they appear to be low in their numbers; hence, there is a need for more investment. The solar home systems appear to be in abundance.

Table 2. Some off-grid plants in Nigeria

S/N	off-grid plant	Location	Capacity (MW)	Performance	Present status
1	Nigeria Breweries Plc	Ibadan, Oyo State	0.663	Optimal	Active
2	Alex Ekwueme Federal University	Ndufu Alike-Ikwo, Ebonyi State	2.8	Optimal	Active
3	Usman Dam Water Treatment Plant	Bwari, Abuja.	1.52	Optimal	Active
4	Usmanu Danfodiyo University	Sokoto, Sokoto State	2	Optimal	Active
5	Nnamdi Azikiwe University	Awka, Anambra State	2.5	Optimal	Active
6	Bayero University, Kano (Buk)	Kano, Kano State	7.1	Optimal	Active
7	Federal University of Agriculture, Makurdi (Funai)	FUNAI, Benue State	8.25	Optimal	Active
8	Federal University Of Petroleum, Effurun	Effurun, Delta State	1.35	Optimal	Active

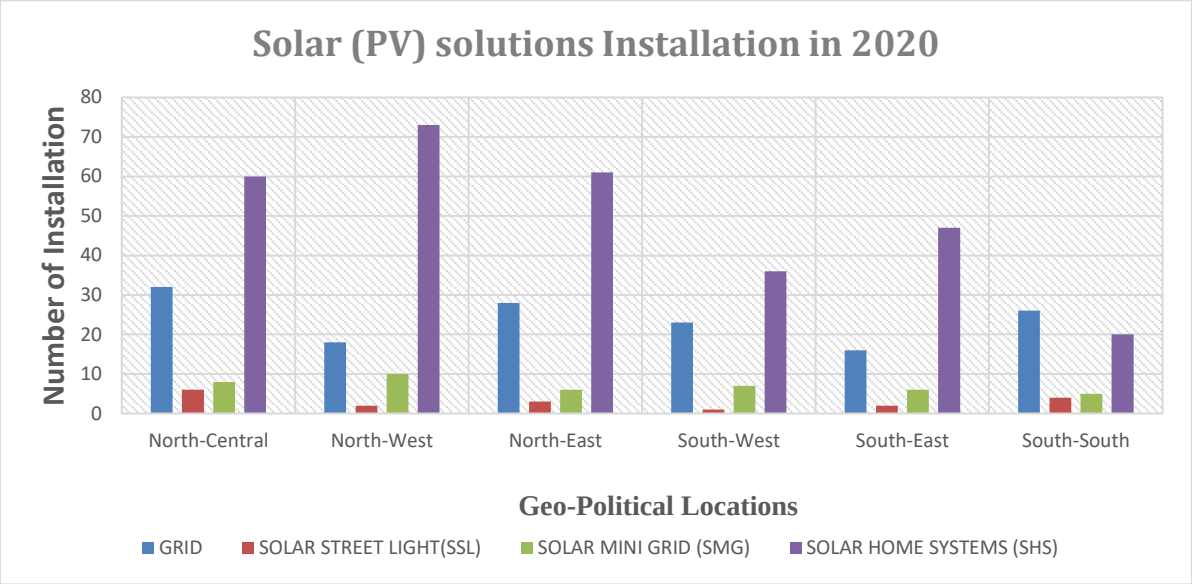


Fig. 1. Solar (PV) Solutions Installation in 2020

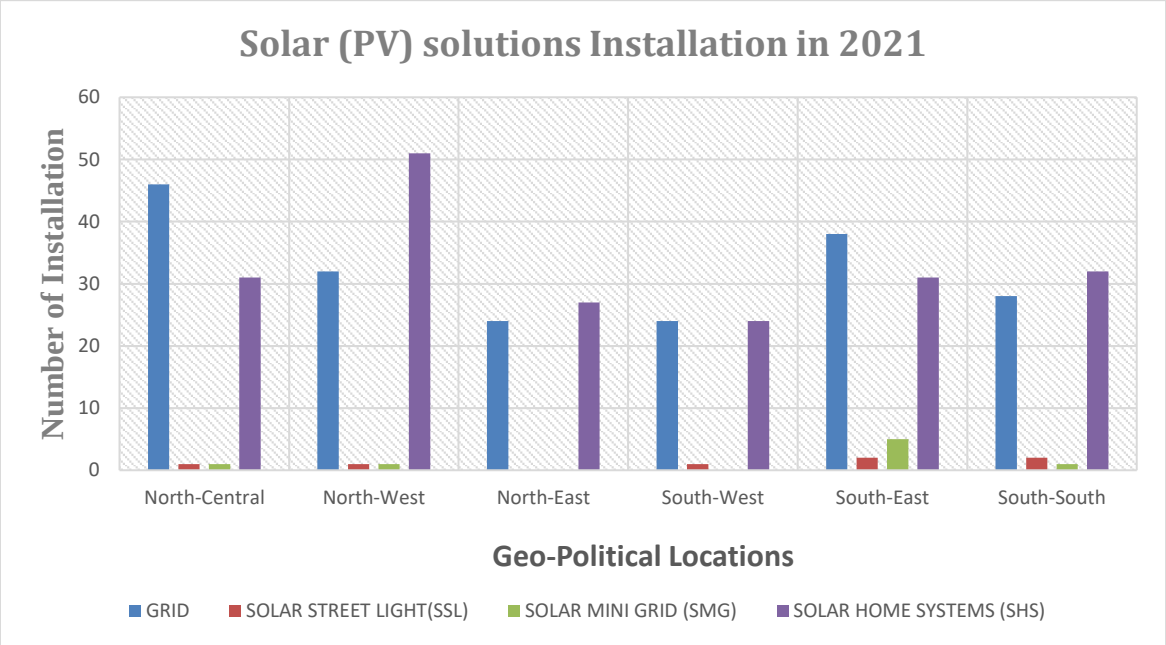


Fig. 2. Solar (PV) solutions installation in 2021

In 2021, considering the same locations, there appears to be an appreciable improvement in the number of Grid plants compared to that of 2020. It records more in the North-Central and least in the North-East and South-East. In the same vein, like that of 2020, the Solar Street Light and Solar Mini Grid were reported to be very low this year, even lower than the previous year. Again, attention is needed for investment in these areas.

The presence of Solar Home Systems in these locations signifies a good number of users. This can also be attributed to its low economic viability. It can be afforded at a very low price.

In 2022, a substantial increase in the number of Solar Street Light plants was recorded. It indicates how widespread the Solar Street Light has gone in Nigeria. However, the count of grid plants in these regions during the same period was comparatively lower. Solar Street Light plant records 49% more than the solar grid.

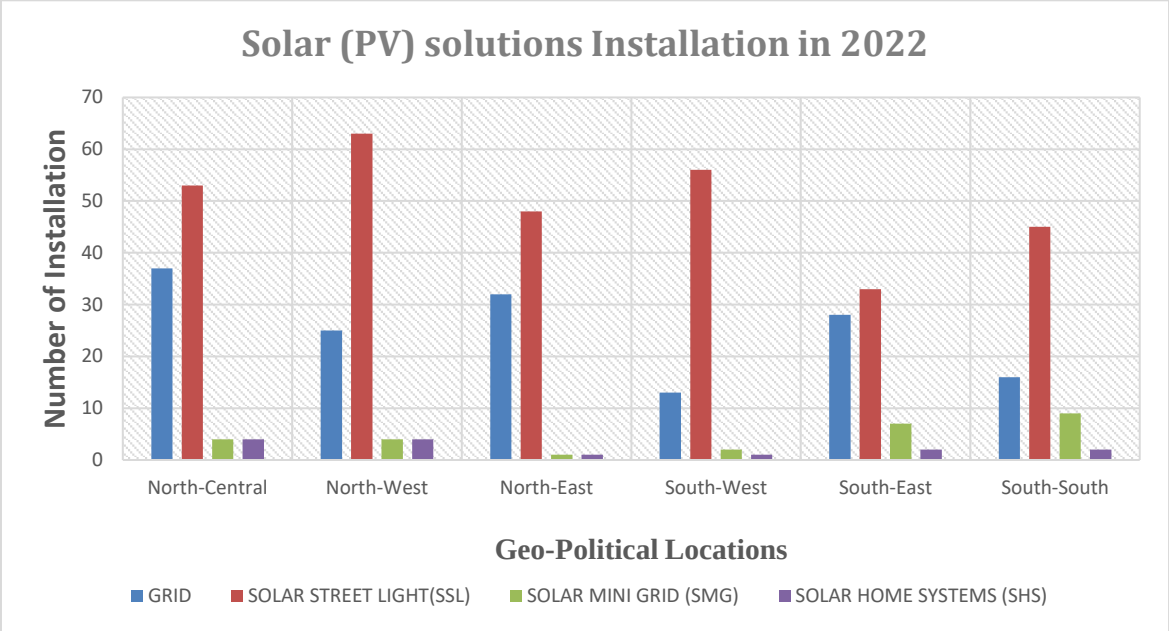


Fig. 3. Solar (PV) solutions installation in 2022

This year, the solar mini-grid and solar home systems appear to be low across the regions. The statistics of 2022, therefore call for more investment in grid plants to reach especially the remote and underserved regions.

The examination of off-grid power plants in Nigeria revealed valuable insights about their geographical dispersion, installed capacity, operational efficacy, and present status. By identifying these specific details, the research aimed to offer a thorough portrayal of the off-grid power landscape in the country.

5. CONCLUSION

Off-grid power plants in Nigeria have been identified. The assessment involves examining their location, capacity, operational performance, and current status. It's imperative to know that the advancement in off-grid plants and renewable energy initiatives is liable to change. This could be influenced by factors such as changes in government policies, technological innovations, and global energy trends.

The Nigerian government is implementing a combination of off-grid and on-grid power projects to provide sustainable and clean electricity to millions. The Off-Grid Electrification Strategy aims to build 10,000 mini-grids by 2023, supplying 250,000 SMEs and 14% of the population. With the World Bank's support, the Nigeria Electrification Project has already provided electricity to over 5 million people and generated 5,000 green jobs. Decentralised energy systems can improve energy efficiency, facilitate economic activity and improve livelihoods in remote locations while providing a range of business models that benefit enterprises, landowners, and rural communities.

The study emphasized the decentralization of off-grid solutions among federal, state, and local governments. This distributed approach would speed up the execution of off-grid projects and the long-term plan actualization. The variation of off-grid power plants and other renewable solutions across diverse regions has the potential to exert political influence on a nation like Nigeria by shaping perceptions of governance, dedication to sustainability, and resilience to disasters. The research contributes to knowledge by furnishing a thorough and current comprehension of Nigeria's off-grid power sector. It extends the existing body of literature by presenting precise details on the geographical distribution, capacities, operational efficiency, and current status of off-grid power plants. This information holds significance not only for Nigeria but also for other regions or nations considering similar off-grid power projects. The study on off-grid power plants in Nigeria is instrumental in addressing crucial knowledge voids, delivering practical insights, and acting as a valuable reference for stakeholders engaged in energy planning, policy formulation, and investment choices.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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