Left in the Dark:
Spatial Analysis of Energy Access For Social Services in Nigeria

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Abstract. The forced interconnectivity to modern energy systems has been a problem in Nigeria, particularly in rural and underserved areas, where a lack of access to electricity hinders development outcomes. This paper presents a spatial, data-based investigation using the Energy Access Explorer (EAE) platform to identify high-priority regions requiring decentralised energy action. The study ensures that Local Government Areas (LGAs) are evaluated and ranked based on their need and feasibility for off-grid energy solutions using a multi-criteria decision framework that considers grid proximity and incorporates existing solar potential. It analyses Fune in Yobe State and Ardo Kola in Taraba State. The researchers identified Taraba State as an ideal intervention area because it combines low electrification levels, high poverty rates, and the presence of unelectrified clinics and schools. On the contrary, Cross River State, specifically Odukpani, was not considered a priority due to its relatively better wealth parameters and improved access to infrastructure. The findings highlight the effectiveness of joined-up spatial devices in creating fair, evidence-based energy planning. The paper has a role to play in the existing academic literature on sustainable energy use. It has provided practical recommendations for the realisation of Sustainable Development Goal 7 in Nigeria and similar contexts.

Keyword: Energy Access; Nigeria; Electrification; Spatial Analysis.

INTRODUCTION

Energy is a basic service that is core to socioeconomic development and a person's sociological well-being. However, in 2022, approximately 759 million people lacked access to electricity, of whom 570 million were in Sub-Saharan Africa – the region that accounts for over 80 million of the global population without access to electricity [1, 2]. In Nigeria, the largest country in Africa, more than 90 million of the nearly 230 million residents are not connected to the grid, representing an uncounted number of unelectrified people worldwide [1].

Such disparities in access are getting worse. In 2022, the number of people without access to electricity also showed an upward trend, partly due to a series of shocks that occurred world-wide, stemming from the COVID-19 pandemic, inflationary pressures, and disruptions in international energy markets [1]. Local weather extremes, including cyclical droughts and flooding in Sub-Saharan Africa, are further deterrents to infrastructure implementation and exacerbate energy poverty.

The energy suffering is also primarily associated with rural areas: 8 out of 10 people without access to electricity live in rural areas [1], implying significant spatial inequalities. This fact underscores the urgency of consistently achieving tangible progress on Sustainable Development Goal 7, which aims to ensure that affordable, reliable, sustainable, and modern energy is available to all by 2030 [3]. In addition, reliable energy is directly relevant to 125 of the 169 SDG targets,

74 of which are related to health, education, and gender equality [4].

Energy is instrumental to the operation of vital processes in healthcare and education, including managing vaccine cold chains, operating night learning facilities, providing online learning resources, and delivering emergency department medical care. Without it, especially in underserved communities, institutions are incapacitated, significantly impeding service provision.

The growing body of literature attests to the significant impact that reliable electrical access near schools and clinics would have on health and educational progress. More electrified facilities tend to be well prepared to provide skilled care during birth, store vaccines properly, and have trained staff. E-schools also show high achievement, attendance, and teacher retention among students [5–7]. These interrelations underscore the need to align energy access efforts with the population's service-delivery goals.

Investment decisions on energy need to consider transparent, spatially explicit planning instruments based on robust data to avoid the marginalisation of firms. To this end, the present paper utilises the Energy Access Explorer (EAE) application to outline areas of schools and clinics in Nigeria that are far from grid systems, determine their solar potential, and identify those at risk.

The findings will:

1) Illuminate critical energy service mismatches impacting public institutions;

2) Reveal high-priority zones where off-grid solutions, such as solar mini-grids, can be deployed cost-effectively;

3) Support coordinated infrastructure planning between the energy, health, and education sectors.

This study presents a new policy-oriented vision of access to energy, foregrounding social infrastructure and forecasting the institutional structures required to support vulnerable populations in public services. The results could help guide Nigerian policymakers, development partners, and planners in aligning electrification programs more effectively with their development goals, thereby enhancing the quality of service and spatial equity.

The following *research questions* guide this study:

1) Where in Nigeria are public service health clinics and school facilities located far from existing electricity infrastructure?

2) Do these unelectricfied service facilities coincide with high solar energy potential and significant population presence?

Which local government areas (LGAs) should be prioritised for decentralised electrification based on overlapping indicators of energy deprivation, solar viability, and social need (e.g., poverty and population density)

Based on the research questions, the study tests the following *hypothesis*:

H1: A significant proportion of health and education facilities in Nigeria are located more than 5 km away from existing electricity grid infrastructure.

H2: Areas with unelectrified zones cause high-poverty, high-density populations, indicating needs and impact

This section focuses on the spatial analysis of energy requirements in three states in Nigeria. With the aid of the Energy Access Explorer (EAE), we have implemented a systematic, data-driven approach to identifying and prioritising underserved communities across a range of criteria. The multi-criteria analysis and formal AOI (Area of Interest) selection are the concluding points of the work.

Literature Review

Measurements of access and development outcomes of energy. Access to quality electricity is closely linked to improved health, educational outcomes, and overall well-being. Electrified clinics in health care settings are more likely to deliver the most critical services, including safe childbirth, vaccine refrigeration, and emergency services [5]. Authors [8] conducted a study in Rwanda and observed that electrification of rural health facilities led to significant improvements in patient visits and service quality.

Authors [7] used Tanzanian data to demonstrate improved academic performance, teacher retention, and school attendance in schools with a solar microgrid. Likewise, source [6] notes that electrification reduces dropout rates by enabling longer study hours and the use of digital learning tools.

The above studies demonstrate the economic and social significance of energy access, particularly in delivering services to the masses. They, however, fail to deliver spatial diagnostics of where these mismatches occur, a gap this study aims to address.

Inequality and Gaps in Infrastructure. Recent developments in development economics have placed greater focus on the role of geographic differences in service access. Authors [9] find that there is chronic spatial disparity in infrastructure across African countries, which is associated with income and opportunity disparities. Authors [10] use geospatial data (e.g., night lights, road networks) to analyse patterns of economic development in unsurveyed areas.

In Nigeria, authors [11] mapped electricity access and found that infrastructure is not always available to meet population or service needs, particularly in rural regions. Nonetheless, the precise relationship between energy infrastructure and the location of public services such as schools and clinics – a classical lacuna in integrated development planning – has not been investigated.

Nigerian Energy Access Planning Tools and Nigerian Environment. To support electrification planning using various spatial layers, planning tools such as Energy Access Explorer, OnSSET, and GEOSIM are gaining popularity [12]. These tools support least-cost electrification planning by combining demographic, infrastructure, and energy potential data.

Nigeria has not fully exploited the potential of the EAE, unlike Uganda, Kenya, and Tanzania, which have utilised it to support their electrification rollouts. Authors [13] analysed data from Nigerian clinics and found that power deficits reduce the quality of healthcare delivery; however, they did not apply spatial diagnostics and instead relied on survey averages. Compared to prior studies, this study utilises EAE spatial layers to locate and measure unelectrified infrastructure for public services, providing new insights that can inform strategies for electrification and social investment.

Literature Gap Summary. Although evidence of a strong association between energy access and better public service outcomes is available, little literature examines where public facilities are not close to the grid, whether locations have feasible off-grid solar systems, and how distribution is distributed across states or LGAs in Nigeria.

This paper bridges the gap between the worlds of energy access and service delivery, as well as geographic targeting, by utilising spatially disaggregated, publicly available data.

METHOD

This paper uses a geospatial multi-criteria decision analysis (MCDA) to identify and rank underserved regions in Nigeria for intervention in energy decentralisation. The methodology combines spatial data layers on infrastructure, socioeconomic conditions, energy potential, and public facilities to systematically evaluate areas where off-grid solar solutions can produce the highest development impact. The Energy Access Explorer (EAE) platform, an open-source geospatial application that facilitates evidence-based planning for electrification, was used to conduct the analysis.

Research Design and Analytical Framework. The study is an exploratory, cross-sectional spatial analysis designed to map energy access disparities and determine priority intervention areas within Nigeria. The authors will organise the paper around the three main analytical aims;

1) Spatial mapping of the public facilities of services (schools and health clinics) and the current infrastructure of electricity grid facilities.

2) Determination of the potential of renewable energy sources (solar irradiance) in locations that have no access to the grid.

3) Prioritisation of areas of intervention based on a multi-criteria framework, which combines both need factors (poverty, remoteness) and feasibility factors (solar potential, population density).

The analysis framework is informed by the fact that proper energy planning should be spatial and multidimensional, focusing not only on technical viability but also on social fairness, infrastructure, and economic feasibility. This method aligns with best practices in least-cost electrification modelling and spatial development planning [12, 14].

Conceptual Model. The paper defines access priority to energy based on four dimensions:

Keeping Infrastructure Gap: Distance to the national electricity grid (indicating grid extension cost and the urgency of finding off-grid solutions)

1) Technical Feasibility: Solar irradiance potential (Global Horizontal Irradiance, GHI).

2) Socioeconomic Need: Relative Wealth Index (RWI) as a measure of poverty and powerlessness.

3) Impact Potential: Population density, unelectrified social facilities (schools, clinics) are present.

Regions that score highly on these dimensions are ideal for deploying decentralised solar energy.

Study Area and Scope. The case focuses on Nigeria, the most populous nation in sub-Saharan Africa, with an estimated population of 230 million, of whom about 90 million have no access to electricity [1]. Nigeria's large geographic size, topography, and significant infrastructure development inequality make it an ideal case for a spatial analysis of energy access.

Areas of Interest (AOIs) Selection. The researchers specifically chose three states for evaluation after preliminarily reviewing the national-level energy access maps created by the EAE:

1) Yobe state (Northeastern Nigeria): High energy poverty, low population density, and high distance to grid infrastructure characterise the state.

2) Taraba State (North-central Nigeria): It has moderate population density, grid cover, and rural settlements.

3) Cross River State (Southern Nigeria): Added as a comparative example, having a relatively good infrastructure and wealth indicators.

In each state, Local Government Areas (LGAs) were selected for assessment, using a detailed spatial analysis and naked-eye observation to examine facility groupings, grid proximity, and initial socioeconomic variables. The selected LGAs were: Fune LGA (Yobe State); Ardo-Kola LGA (Taraba State); Odukpani LGA (Cross River State).

The researchers identified these AOIs through a series of spatial explorations on the EAE platform, guided by data rather than random selection.

Data Sources and Geospatial Tools. Energy is widely accessible via the Energy Access Explorer (EAE) Platform. The primary analytical instrument used in this study is the Energy Access Explorer (EAE), a web-based geospatial decision-support tool developed by the World Resources Institute (WRI) in collaboration with national governments and other international partners.

EAE combines various spatial data sets in a Web-Based Interactive Map that enables users to overlay and query the information about: Electricity grid networks (transmission and distribution lines); Schools, health facilities, and other social infrastructural locations; Population density and patterns of settlement; Solar irradiance (Global Horizontal Irradiance); Socioeconomic (Relative Wealth Index); Topography, land use, and the conservation areas.

The researchers utilised a platform designed specifically for energy access planning, which has been implemented in countries such as Kenya, Tanzania, Uganda, and Nigeria, for data storage, analytical query space, layer overlay, and graphical evaluation in this experiment.

Key Data Layers. Spatial data layers were used in the analysis as follows:

1) Infrastructure of Electricity Grids.

Source: the Nigerian Transmission Company of Nigeria (TCN) and Distribution Companies (DisCos) merged with EAE.

Description: The geospatial vector data of the position of the high-voltage transmission lines and the medium-voltage distribution network.

Application: This application determines the distance between any point (facility or settlement) and the closest grid connection.

2) Health facilities and Schools.

Source: the Federal Ministry of Health, the Federal Ministry of Education, and OpenStreetMap (OSM), which EAE in Nigeria validates.

Description: The positions of primary healthcare centres, clinics, primary schools, and secondary schools.

Application: Determination of social infrastructure which is unelectrified and needs access to energy.

3) Solar Irradiance (Global Horizontal Irradiance, GHI).

Clone: Global Solar Atlas, World Bank and Solargis.

Description: Raster data of annual average solar irradiance in $kWh/m^2/year$ at a spatial resolution of about 250 meters.

Application: Evaluation of the technical appropriateness of solar photovoltaic (PV) systems.

4) Population Density.

Source: WorldPop and Facebook High-Resolution Settlement Layer (HRSL).

Description: 100-meter resolution population estimates in grids.

Application: Estimation of possible beneficiaries and sub-demand of service in each AOI.

5) Relative Wealth Index (RWI).

Source: Developed by the Centre for Effective Global Action (CEGA) at UC Berkeley in collaboration with Facebook (Meta).

Description: Machine learning estimates relative wealth using satellite imagery, cell phone connectivity, and census data. The RWI ranges from -2 (poorest) to +2 (wealthiest) and standardises values at the national level.

Application: Proxy indicator of poverty and socioeconomic vulnerability, which is utilised to prioritise the areas with the highest need.

The researchers used the EAE platform to access and process all datasets between August and September 2024. The time coverage and spatial resolution of the data differed: the majority of infrastructure and facility data represented the state of affairs as of 2022-2023, whereas socioeconomic indicators were based on estimates from 2020 to 2022.

Spatial Analysis Procedures. The researchers conducted the spatial analysis in four sequential phases:

Stage 1: Screening at the National Level. The initial step was a national space screening to identify densely populated areas with unelectrified social facilities and areas with low grid coverage. The overlay of the layers in EAE was as follows, using the interactive mapping interface: grid infrastructure (including transmission lines and distribution lines), schools and health facilities, the Relative Wealth Index (RWI), and population density.

Hotspots due to: Visual inspection and spatial queries were applied to identify where: There were several social amenities; There was no grid infrastructure, or it was remote (>10 km); RWI showed that poverty was present (values below -0.3).

The screening process resulted in the creation of a pre-list of candidate states and LGAs to be assessed in more detail.

Stage 2: AOI-Specific Spatial Assessment. In each of the three chosen AOIs (Fune, Ardo-Kola, and Odukpani), the researchers extracted and analysed the following parameters to obtain finer spatial measurements: Grid Proximity: The straight-line distance (in kilometres) of the centroid of the AOI to the closest point on the national electricity grid; Retrieved through the EAE distance measurement tool.

Solar Irradiance (GHI): Average Global Horizontal Irradiance in the AOI boundary in $kWh/m^2/year$; Taken out of the Solar Atlas layer incorporated in EAE.

Population Density: The mean population density in the AOI is expressed in square kilometres; accessed using WorldPop gridded population data.

Relative Wealth Index (RWI): Mean RWI value of the AOI boundary; Taken out of the CEGA-Meta RWI layer.

These parameters were measured and used in each AOI, then tabulated in a summary table used for comparative analysis (see Results, Table 1).

Stage 3: Multi-Criteria Decision Analysis (MCDA). The researchers formulated a multi-criteria scoring framework to enable an objective comparison and prioritisation of the three AOIs. AOIs were rated on four criteria on a standardised 0-2 scale, with higher scores indicating greater appropriateness for off-grid solar intervention.

Scoring Criteria and Thresholds

Grid Distance Score: 0 points: < 5 km (grid extension feasible); 1 point: 5-30 km (moderate remoteness); 2 points: > 30 km (extreme remoteness; off-grid preferred).

Solar Irradiance Score: 0 points: < 1700 $kWh/m^2/year$ (low solar potential); 1 point: 1700-1999 $kWh/m^2/year$ (moderate solar potential); 2 points: ≥ 2000 $kWh/m^2/year$ (high solar potential).

Population Density Score: 0 points: 0 people/km^2 (uninhabited); 1 point: 1-25 people/km^2 (low density); 2 points: > 25 people/km^2 (moderate to high density).

Relative Wealth Index Score: 0 points: RWI > 0 (above-average wealth); 1 point: RWI between -0.49 and 0 (moderate poverty); 2 points: RWI <- -0.5 (extreme poverty).

The thresholds were established based on: a) Literature on least-cost electrification and so-

lar viability [12]; b) Nigeria-specific economic and infrastructure conditions; c) Practical feasibility considerations for mini-grid deployment.

Total Score Calculation: Each AOI received a total score ranging from 0 to 8 (sum of scores across the four criteria). Higher total scores indicate areas with the most fantastic combination of need and feasibility for off-grid solar intervention.

Stage 4: Validation and Final AOI Selection. The final stage involved validation of the scoring results through: a) Cross-checking spatial patterns against national-level maps; b) Visual inspection of facility distribution within high-scoring AOIs; c) Qualitative assessment of accessibility, security, and infrastructure context.

AOIs scoring six or above (out of 8) were classified as high-priority zones suitable for immediate intervention planning. AOIs with scores below four were classified as low-priority zones, better suited for grid extension or alternative interventions.

RESULTS AND DISCUSSION

The section presents the results of the spatial analysis conducted on the Energy Access Explorer (EAE) platform to identify priority areas for decentralised energy interventions in Nigeria. The findings will be structured according to the multi-criteria assessment model, starting with national-level observations, then further divided into Local Government Area (LGA)-specific assessments, and concluding with the prioritisation of the results.

National-Level Energy Access Overview. The EAE-based national-level assessment demonstrated considerable spatial differences in energy accessibility in Nigeria, with significant concentrations of underserved areas in the northern and northeastern parts.

ASSISTANCE NEED INDEX
Areas where financial assistance is needed

Area share
943,047 km^2

Population share
217,023,487 people

Low   Medium   High

Figure 1 − Assistance Need Index - National Distribution

Figure 1 presents the distribution of areas by level of assistance need (low, medium, and high). High-need regions cover about 40% of the country's total territory and account for a disproportionate share of the unelectrified social infrastructure. The graphic data show that energy poverty exhibits a spatial concentration pattern, with the worst disparities in rural areas distant from urban settlements and grid infrastructure.
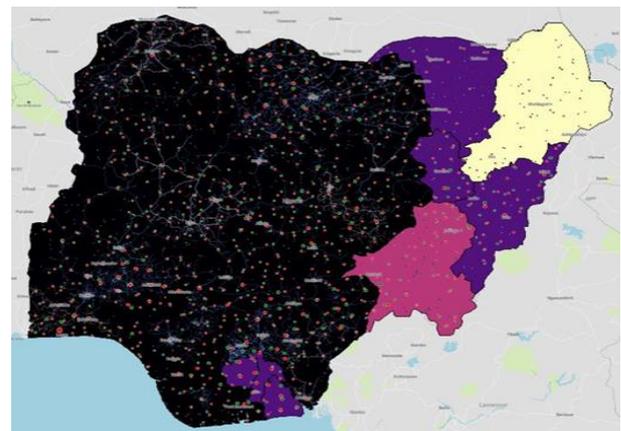

Figure 2 − Spatial Distribution of Grid Infrastructure and Social Facilities

Figure 2 is a map illustrating the relationship between grid infrastructure (represented by transmission lines), schools, and health clinics in Nigeria. It is observable by the naked eye that there are large geographic areas with no social facilities within proximity of grid access. This disfigurement is particularly pronounced in the northeast (Yobe, Borno) and in parts of the northwest and middle belt, which supports the hypothesis that public service infrastructure is often installed without a matching energy supply.

The Characteristics of Area of Interest (AOI). The researchers first determined three Areas of Interest based on preliminary mapping: Fune LGA in Yobe State, Ardo-Kola LGA in Taraba State, and Odukpani LGA in Cross River State. They evaluated each area across four major dimensions: grid proximity, solar potential, population density, and wealth status.

Table 1 summarises the raw spatial and socioeconomic data for each AOI. Fune and Ardo-Kola are very remote from the national grid (65 km and 95 km, respectively), whereas Odukpani is within 1 km of the grid. Yobe has the highest solar irradiance (2192 kWh/m^2), and Taraba (2011 kWh/m^2) has the second-highest, both of which

are above the economically viable threshold for solar deployment. Cross River has relatively low solar potential (1640 kWh/m²). The wealth indicators indicate that Fune and Ardo-Kola are the poorest neighbourhoods in Nigeria, with RWIs of -0.79 and -0.49, respectively. At the same time, Odukpani has an RWI of -0.18, indicating that the neighbourhoods are relatively well-off.

Table 1 – Summary of Spatial and Socioeconomic Characteristics by AOI

AOI (State)	Grid Distance	GHI (Solar)	Population Density	RWI	Observations
Yobe (Fune)	65 km	2192 kWh/m²	6 ppl/km²	-0.79	Very poor, far from the grid, good solar
Taraba (Ardo-Kola)	95 km	2011 kWh/m²	29 ppl/km²	-0.49	Poor, moderate population, far from the grid
Cross River (Odukpani)	1 km	1640 kWh/m²	0 ppl/km²	-0.18	Near the grid, low solar, empty area

The spatial context of Fune LGA is shown in Figure 3. Given the area's features, settlement patterns are sparse, grid infrastructure is limited, and solar irradiance is high. Several non-electrified health and education establishments can be observed scattered across low-income land. This region is a good candidate for standalone solar mini-grids due to its extreme remoteness and high solar potential.

The distance to the grid (95 km) is even greater, and there are no social facilities with electricity. The higher population density implies more potential beneficiaries per investment; however, the solar potential is slightly lower than in Yobe.

The sampling area of Creek town in Odukpani LGA is shown in Figure 5.
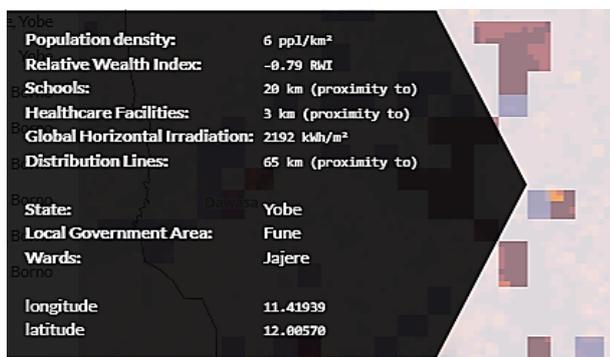
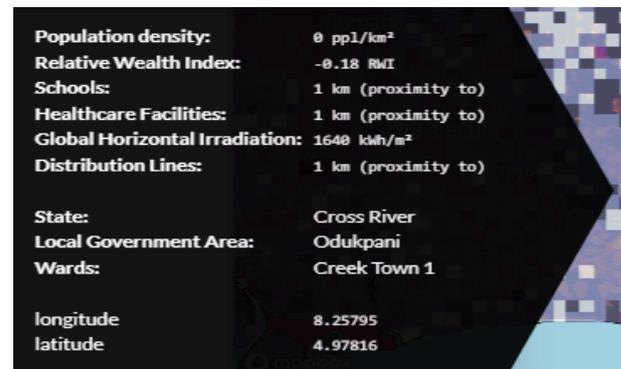

Figure 3 – Fune LGA, Yobe State - Spatial Attributes

Figure 5 – Cross River State (Creek Town Area), Odukpani LGA

Figure 4 displays Ardo-Kala LGA because of its proximity to Fune. Still, it has a higher population density (29 people/km² vs. 6).
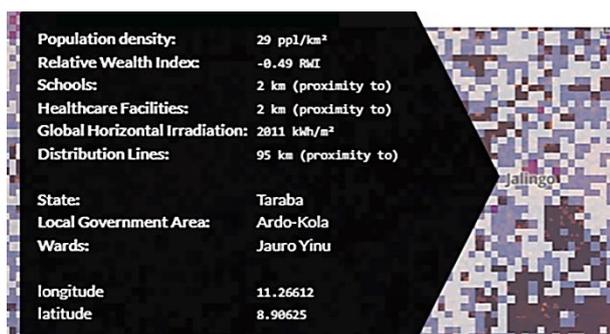

Figure 4 – Ardo-Kola LGA, Taraba State - Spatial Attributes

This place is also closer to grid infrastructure (immediately, 1 km) and is comparatively richer than the two previous AOIs. The sampled zone has uninhabited characteristics (0 people/km²), possibly due to localised geographic features rather than the LGA profile. However, the site's proximity to the grid and improved economic indicators make this site a lower priority for off-grid intervention.

Multi-Criteria Scoring and Prioritisation. To objectively rank the three AOIs, a multi-criteria decision model was used with a uniform 0-2 scoring system for four key parameters: grid distance,

solar irradiance, population density, and relative wealth index.

Table 2 presents the scoring levels used to determine the ordinal ranking of continuous variables.

Table 2 – Multi-Criteria Scoring Framework

Criterion	Score 0	Score 1	Score 2
Grid Distance	<5 km	5–30 km	>30 km
Solar Irradiance (GHI)	<1700	1700–1999	≥2000
Population Density	0	1–25 ppl/km²	>25 ppl/km²
Relative Wealth Index (RWI)	>0	-0.49 to 0	≤ -0.5

The high scores suggest an increased need and/or appropriateness for off-grid solar intervention. For example, regions more than 30 km from the grid are assigned a maximum of 1 (2), indicating the high demand for decentralised solutions. Similarly, extreme poverty (RWI < 0.5) and high solar irradiance ($\geq$ 2000 kWh/m²) also score maximum points, indicating that both aspects require high development requirements and technical feasibility, respectively.

Table 3 presents the final prioritisation scores. Yobe (Fune) and Taraba (Ardo-Kola) scored 7 out of 8, which is almost the maximum level of suitability of off-grid solar intervention.

Table 3 – Final Multi-Criteria Scores by AOI

AOI	Grid (km)	GHI	Pop Density	RWI	Grid Score	Solar Score	Pop Score	RWI Score	Total (8 max)
Yobe (Fune)	65	2192	6	-0.79	2	2	1	2	7
Taraba (Ardo-Kola)	95	2011	29	-0.49	2	2	2	1	7
Cross River (Odukpani)	1	1640	0	-0.18	0	0	0	1	1

Fune also achieved high ratings for grid remoteness, solar potential, and the severity of overty. In contrast, Ardo-Kala is due to its high score. On the contrary, Odukpani had a low score of 1 out of 8, primarily due to a marginal wealth penalty. It could not be considered a priority intervention zone due to its proximity to the grid, low solar potential, and the lack of population in the sampled area. These findings provide substantial support for Hypotheses H1 and H3, which suggest that unelectrified facilities are disproportionately concentrated in impoverished, remote regions.

The results of this study strongly support the central thesis formulated in the introduction: energy poverty in Nigeria is not randomly distributed. It is characterised by specific spatial forms linked to the lack of infrastructural provision, systemic poverty, and past underdevelopment. The Fune Local Government Area in Yobe State and Ardo-Kola Local Government Area in Taraba State, which are characterised as high-priority zones of intervention, align with patterns of regional inequality with historical roots. The southern states have been older and poorer in electrification, poorer in health, and have lower educational levels than the northern states.

As was shown in the multi-criteria analysis, those areas have all been found to be high not on one dimension of deprivation, but on a multiplicity of overlapping regions of vulnerability, such as extreme remoteness to grid infrastructure, extreme economic poverty (RWI -0.5), or the availability in the neighbourhood of some critical yet unelectrified social facilities. To their credit, this intersectionality makes any effort to develop electricity in such areas more effective, as such development would have the added developmental advantage of improving access to and provision of healthcare services, boosting educational attainment, and providing economic opportunities.

The decision to give the Odukpani Local Government Area priority was based on unbiased grounds, not on arbitrary grounds. Although there are instances of energy poverty in Cross River State, the ease of access to the current grid facility in the sampled area (1 km) and relatively favourable wealth indicators make it a lower-priority area for utilising geographically scarce off-grid resources. This distinction can be used to highlight the importance of data-driven targeting, where not every underserved area can receive an equal intervention, or such an intervention must be of a specific nature.

Alignment with Existing Literature. The results support and expand the previous studies of energy access and spatial disparity in sub-Saharan Africa. In line with the findings of authors [11], who have recorded widespread spatial incommensuratenesses between the accessibility of infrastructure and demand at the population scales in Nigeria, the proposed research contributes to the body of evidence on social facilities, namely schools and clinics, in a systematic location in areas with no access to the national grid; this is not only a problem of lagging infrastructure, but a broader issue of inequalities in how services and infrastructure are provided and funded by the government.

The research also confirms the theoretical framework proposed by authors [10], who argued for the use of geospatial data, including night-light visualisation and urban networks, in development economics. This study has illustrated how the synthesis of various spatial layers – grid proximity, solar irradiance, and population density – afforded a rich set of estimates that can be used to facilitate actionable knowledge for policymakers.

Additionally, the findings corroborate the emerging view in the energy-access literature that decentralised renewable energy infrastructure, specifically solar mini-grids, is a viable and, in many instances, superior alternative to grid penetration in remote, low-reliance regions [15, 16]. Both the Fune and Ardo-Kola have solar irradiance readings exceeding 2000 kWh/m^2, well above the recommended threshold for cost-efficient deployment of photovoltaic cells. This technical capability, combined with the prohibitive grid-extension costs (ranging from 65 to 95 km), makes solar mini-grids the economically rational option at these sites.

The existence of a positive correlation between the presence of an electrified social backbone and enhanced developmental results has been proven by authors [7] in the case of Tanzania and authors [8] in the case of Rwanda; hence, it is justifiable to put schools and clinics higher in the electrification hierarchy to improve developmental outcomes. The researchers build on that reasoning to explain why those facilities remain unelectrified and to show how they can logically identify and rank them using open-access geospatial tools.

The findings and methodology adopted in this paper have ample implications for energy policy and development planning in Nigeria and other similar situations:

This method reduces the risk of elite capture and political favouritism in resource allocation by using open, replicable criteria to rank areas of intervention. The multi-criteria model focuses investments on areas with high needs – such as poverty, remoteness, and a lack of electrified community structures – and high potential impact, thereby achieving greater equity and effectiveness in infrastructure development.

The research indicates the usefulness of cross-sectoral integration of energy, health, and education ministries; this is not just an isolated electrification plan; it focuses on the infrastructure of public services, so that any energy investments directly improve the operations of schools and clinics; this aligns with SDG 7's view of energy as a contributing factor to broader developmental objectives, such as health (SDG 3), education (SDG 4), and poverty reduction (SDG 1).

The approach used in this case, which relies on open-access tools such as the Energy Access Explorer, can be further implemented in other states of Nigeria, other African nations, or even other industries (e.g., access to water, agricultural extension). Researchers can now access data layers (facility locations, grid networks, solar potential, and wealth indices) more readily in sub-Saharan Africa than in other regions, making it easy to transfer this approach.

Development Partners and Investors Evidence. For multilateral organisations (the World Bank and the AfDB), bilateral donors, and impact investors, this study can provide a template for evidence-based project identification. Instead of anecdotal needs assessments or politically influenced site selection, geospatial multi-criteria analysis can enable stakeholders to identify areas with high returns on investment that meet development requirements.

The researchers developed a strong methodology, but should mention several of its limitations:
Narrowness of AOI Assortment. The researchers studied only three candidate areas in three states. Still, they could extend the analysis to all 774 LGAs in Nigeria to create a complete national prioritisation map and allocate resources more strategically. Computational constraints and data availability limited this initial assessment, but the framework is scalable.

The paper has three significant contributions:

Methodological Innovation: It demonstrates how evidence-based policy targeting can be implemented through publicly available geospatial platforms, serving as the interface between academic spatial analysis and practical development planning.

Empirical Validation: It provides empirical data at the LGA level on the spatial distribution of energy poverty in Nigeria, addressing a significant gap in the literature and providing a template that can be reproduced in other African settings.

Policy Relevance: The study puts energy access in a new light as a precursor to human development rather than a consumer good by focusing on the infrastructure of the populace (schools and clinics). This approach makes energy planning more consistent with the overall development agenda and strengthens the case for government support of off-grid solutions.

CONCLUSIONS

As discussed, access to energy is not a technical problem but a spatial and socio-political one. The results highlight a focus on energy poverty in Nigeria, particularly in remote, impoverished, and inaccessible areas that are underserved by the available services to the population. This combination perpetuates the cycle of marginalisation. Nevertheless, analyses of the same also identify ways of intervention: regions such as Fune and Ardo-Kala have access to solar resources and populations of a specific size, making decentralised energy solutions both technically feasible and developmentally effective.

Finally, this paper supports the thesis developed in the introduction: that to realise SDG 7 in Nigeria – and, by implication, in sub-Saharan Africa – one must go beyond idealistic ambitions by focusing on spatially specific, information-based planning. The instruments and techniques shown here present a guide to that transition.

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