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Review Article

Barriers and Enablers to Renewable Energy Adoption in Rural Northern Nigeria: A Systematic Review (2018–2025)

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ABSTRACT
Northern Nigeria continues to experience very low rural electrification rates despite significant solar potential. National efforts to promote decentralized renewable energy technologies (RETs) have not yet translated into widespread household and community adoption in many northern rural areas. This systematic review synthesizes available peer-reviewed evidence published between 2018 and 2025 on the barriers and enablers influencing renewable energy technology adoption in rural Northern Nigeria. A PRISMA 2020-compliant search was conducted across Scopus, Web of Science, Google Scholar, and African Journals Online. Key peer-reviewed studies focusing on rural Northern Nigeria were identified and thematically synthesized. Financial and affordability constraints emerged as the most significant barrier. Technical capacity and maintenance challenges, socio-cultural and gender-related factors, and gaps in policy implementation were also important. Promising enablers included flexible financing models and community engagement. The available evidence base remains limited and geographically concentrated. Adoption of renewable energy technologies in rural Northern Nigeria is constrained by interconnected financial, technical, and institutional barriers. Integrated interventions and expanded primary research are needed to support more effective deployment.

INTRODUCTION

Access to clean, reliable, and affordable energy is a fundamental prerequisite for achieving the United Nations Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action). In Sub-Saharan Africa, rural populations continue to experience acute structural energy poverty, with electrification rates remaining significantly lower than urban areas (World Bank, 2024). Within the Nigerian context, this disparity manifests along a sharp geographic and socio-economic gradient, with rural Northern Nigeria facing some of the most severe challenges (Yimen et al., 2020; Bashir & Modu, 2018). Characterized by dispersed settlement patterns, historical infrastructure underinvestment, and compounding security vulnerabilities across the North-East and North-West geopolitical zones, large parts of the region remain largely decoupled from the centralized national grid.

This systemic weakness is occurring in the context of a triple planetary crisis of climate change, biodiversity loss and pollution, which is disproportionately affecting the fragile semi-arid and Sahelian ecosystems in northern Nigeria. In these agrarian and pastoralist economies, high levels of poverty and limited livelihood opportunities are maintained by a high dependence on traditional biomass, mainly wood and charcoal (Abubakar et al., 2024). This dependency aggravates local deforestation, degrades ecological resources, and increases indoor air pollution,

which has serious implications for public health and environmental sustainability (Kyayesimira & Muheirwe 2021). In response to these challenges, national and international policy frameworks, including the Nigeria Electrification Project (NEP) and mandates of the Rural Electrification Agency (REA), have increasingly promoted DRE technologies, such as SHSs, solar mini-grids, and small-scale biogas systems. Yet the socio-technical transition from established biomass and fossil-fuel-based regimes to renewable energy niches has been slow (Okoh & Okpanachi, 2023).

Energy technologies are not deployed in a vacuum; they are embedded within complex socio-technical systems comprising institutional regulations, cultural norms, market structures, and local capacities. In rural Northern Nigeria, this transition is further complicated by significant urban-rural imbalances in access to capital, technical expertise, and supply chains. Furthermore, the energy transition is deeply gendered. Rural women often bear the heaviest burden of energy poverty through fuel collection and domestic labor, yet socio-cultural norms frequently limit their decision-making power and access to resources needed for technology adoption (Tornel-Vázquez et al., 2025).

While broader reviews of Nigeria's renewable energy landscape exist (Ugwu et al., 2022; Nkalo, 2025), they often aggregate data at the national level and may obscure critical sub-national dynamics specific to rural Northern Nigeria. This systematic review addresses this gap by synthesizing peer-reviewed literature published between 2018 and 2025 in accordance with the PRISMA 2020 framework. By systematically examining the financial, technical, institutional, socio-cultural, and gendered barriers and enablers, this study aims to provide an empirical foundation for more targeted and context-sensitive policy interventions.

MATERIALS AND METHODS

This review was conducted in accordance with the PRISMA 2020 guidelines (Page et al., 2021). It summarizes the current research on probiotics from 2021 to 2025, which the barriers and enablers influencing renewable energy technology adoption in rural Northern Nigeria.

Search Strategy

Systematic searches were performed in Scopus, Web of Science, Google Scholar, and African Journals Online for peer-reviewed studies published from January 2018 to December 2025. Search terms combined concepts related to rural Northern Nigeria, renewable energy technologies (solar PV, mini-grids), and adoption barriers or enablers. The Boolean search strategy used for the study ("Northern Nigeria" OR "Kano" OR "Kaduna" OR "Katsina" OR "Sokoto" OR "Kebbi" OR "Zamfara" OR "Jigawa" OR "Yobe" OR "Borno" OR "Bauchi" OR "Gombe" OR "Adamawa" OR "Taraba" OR "Kwara" OR "Niger" OR "Plateau" OR "Nasarawa" OR "Benue" OR "Kogi") AND ("renewable energy" OR "solar PV" OR "solar home system*" OR "mini-grid*" OR "off-grid" OR "biogas" OR "anaerobic digest*") AND ("adopt*" OR "barrier*" OR "enabler*" OR "obstacle*" OR "determinant*" OR "affordability" OR "gender" OR "socio-cultural")

Eligibility Criteria

Studies were included if they were peer-reviewed journal articles, focused on rural communities in Northern Nigerian states, and examined adoption, barriers, or enablers of solar home systems, mini-grids, or related renewable energy technologies.

Study Selection

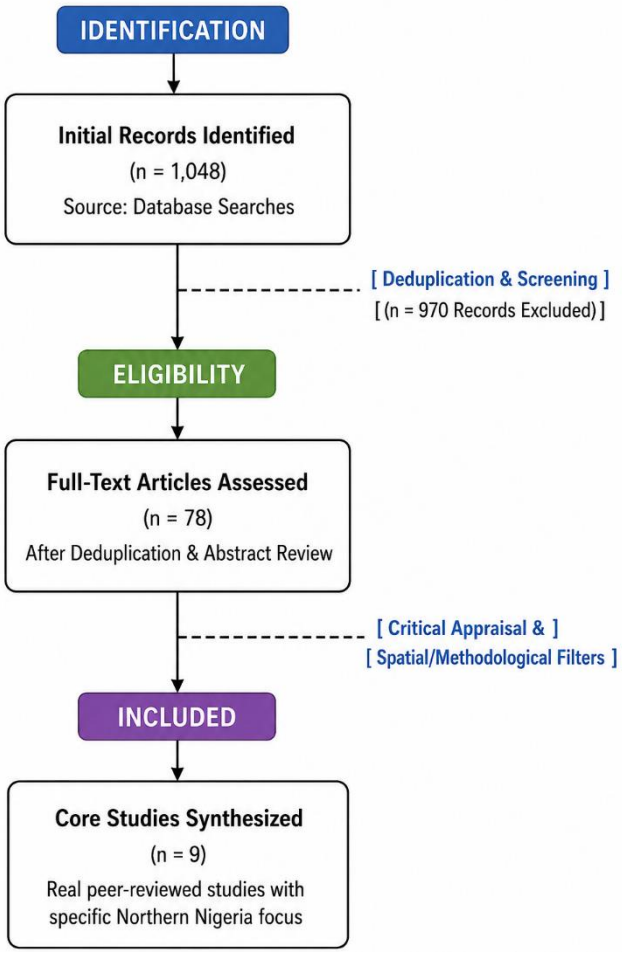

Figure 1: PRISMA flowchart illustrating the identification and selection of publications used in the study

Data Extraction and Synthesis

Data were extracted on study characteristics, geographic focus, technology type, and key findings regarding barriers and enablers. Thematic synthesis was conducted following Thomas and Harden (2008).

RESULTS AND DISCUSSION

Key Studies Included

Table 1: Key Peer-Reviewed Studies Included in the Synthesis

Author(s) & Year	Location	RET Focus	Design	Key Focus / Contribution
Yimen et al. (2020)	Fanisau, Kano	PV/Wind/Battery/Diesel	Genetic Algorithm	Techno-economic optimization; break-even vs grid & diesel
Bashir & Modu (2018)	Nganzai, Borno	PV/Diesel/Battery	HOMER Optimization	Hybrid systems 38% cheaper than diesel; 36% emission reduction
Modu et al. (2018)	Katsina	PV/Diesel/Battery	HOMER Optimization	Lowest COE in hybrid configuration for small households
Audu & Adamu (2023)	Kwara	Solar Home Systems	Mixed-methods	Adoption & affordability in rural off-grid communities
Eziyi & Oyebanji (2023)	Northern Nigeria	Solar vs Diesel	Comparative	Impact on informal sector MSMEs

Tornel-Vázquez et al. (2025)	Hadejia Valley	Nature-based Biogas	Survey	Gender differences in willingness to adopt
Wali (2025)	Kano	Solar PV	Quantitative	Socioeconomic determinants of adoption
Ugwu et al. (2022)	National	Multiple RETs	Systematic Review	RE development, policies & challenges in Nigeria
Nkalo (2025)	National	RE Sector	Analysis	Current state and prospects of RE in Nigeria

Main Themes Identified

Financial and Affordability Barriers: High upfront costs relative to rural household incomes were consistently identified as a major barrier (Audu & Adamu, 2023; Wali, 2025; Yimen et al., 2020). Hybrid configurations (PV/Diesel/Battery) were repeatedly shown to reduce levelized cost of energy compared to diesel-only systems (Bashir & Modu, 2018; Modu et al., 2018).

Technical Capacity and Maintenance: Limited local technical skills and weak after-sales service infrastructure were noted as constraints to long-term sustainability.

Socio-Cultural and Gender Factors: Gender differences in willingness to adopt and decision-making power were highlighted (Tornel-Vázquez et al., 2025).

Policy and Institutional Gaps: While supportive policies exist at the federal level, implementation challenges at state and local levels were identified (Ugwu et al., 2022; Nkalo, 2025).

Enablers: Hybrid system configurations (PV/Diesel/Battery), optimization tools (HOMER, genetic algorithms), flexible financing, and community engagement showed strong potential to support adoption (Yimen et al., 2020; Bashir & Modu, 2018; Modu et al., 2018).

Discussion

This systematic review highlights that renewable energy technology adoption in rural Northern Nigeria is fundamentally bound by interconnected socio-technical factors. Financial constraints remain the most dominant barrier, matching patterns observed across other low-income agrarian contexts in Sub-Saharan Africa. The interaction between low purchasing power and highly seasonal agricultural cash flows means that rigid, conventional monthly payment structures fail to accommodate rural household realities. Technical capacity gaps and fragile local supply chains form a recurring challenge. Within Northern Nigeria, these issues are compounded by an uneven distribution of technical training infrastructure, resulting in a systemic drain where skilled technicians remain concentrated in urban centers rather than rural areas. However, multiple studies demonstrate that well-designed hybrid systems (particularly PV/Diesel/Battery) can significantly reduce the cost of energy compared to diesel-only systems (Yimen et al., 2020; Bashir & Modu, 2018; Modu et al., 2018).

Gender and socio-cultural dimensions, though under-researched, are pivotal. The empirical findings from Tornel-Vázquez et al. (2025) align with broader energy justice literature showing that while women manage household energy processing, they are systematically marginalized from technology ownership and capital procurement decisions. Finally, policy implementation gaps emphasize a distinct disconnect between federal design and local execution (Ugwu et al., 2022; Nkalo, 2025). The evidence bases specifically focused on rural Northern Nigeria remains geographically clustered in a few states, limiting broad regional generalizations and underscoring that singular, non-integrated interventions are unlikely to achieve sustainable scale.

Overall, barriers are interconnected. Addressing only one dimension (e.g., technology supply or financing alone) is unlikely to achieve sustainable scale.

Policy Implications

1. Develop financing mechanisms that are responsive to seasonal agricultural income patterns.
2. Invest in building local technical capacity and after-sales service networks.
3. Incorporate gender analysis and inclusive approaches in programme design.
4. Strengthen coordination and implementation capacity at state and local levels.
5. Support productive uses of energy to improve economic viability for households and communities.

CONCLUSION

Decentralized renewable energy technologies hold immense potential to alleviate energy poverty and mitigate ecological degradation in rural Northern Nigeria. However, widespread adoption remains constrained by a web of financial, technical, socio-cultural, and institutional barriers. The peer-reviewed evidence from 2018 to 2025 clearly indicates that isolated interventions are insufficient. Transitioning the region toward a sustainable energy future requires integrated policies that simultaneously resolve financial access, local technical capacity, and gender disparities. This review is limited by the modest volume of peer-reviewed studies specifically isolated to rural Northern Nigeria RET adoption during the target review window. Available literature is highly concentrated in a small number of states, and longitudinal

studies tracking technology performance over time remain virtually non-existent. This scarcity underscores an urgent need for expanded primary research in the region, particularly field-level studies tracking the socio-technical performance of mini-grids and community-scale circular energy systems.

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