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RESEARCH ARTICLE

Adoption of solar energy as a strategy to mitigate rural-urban migration of youth in Taraba state, Nigeria

Andeskebtso Yohanna Adaki

Department of Sociology, Taraba State University, Jalingo Taraba State, Nigeria

Corresponding Author: Andeskebtso Yohanna Adaki. Email: lordadaki@gmail.com
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Abstract
Rural-urban migration among youth in Taraba State of Nigeria, has increased due to limited economic opportunities and inadequate infrastructure, particularly energy access, in rural areas. This study was conducted to investigate the adoption of solar energy as a sustainable approach to curb this trend by fostering rural development and youth retention. Using a mixed-methods approach, primary data were collected from 300 rural youth and 20 key informants in three local government areas (LGAs) of Taraba State. The study found out that solar energy initiatives enhance livelihood opportunities, reduce energy poverty, and decrease migration intentions by 28%. However, it also found that barriers such as high initial costs and limited awareness persist. Therefore, the study recommends subsidized solar programs and youth-centered training to bolster rural retention.

Keywords: Rural-urban migration; solar energy; energy poverty; youth migration; rural development

Introduction

Rural-urban migration is one of the socio-economic challenges faced in sub-Saharan Africa. It is driven largely by inadequate infrastructure, limited economic opportunities, and poor access to essential services. In Taraba State, of Nigeria, this problem is particularly pronounced among youth aged 15–35, who migrate to urban centers such as Jalingo, Lagos, Abuja even out of Nigeria in search of better livelihoods. With over 70% of the state's population residing in rural areas (National Bureau of Statistics, 2020), the continuous exodus of young people threatens the sustainability of these communities, which intensifies socio-economic disparities between rural and urban areas.
A key factor underpinning this migration trend is energy poverty. Out of the 36 states in Nigeria, Taraba State has the lowest access electricity (Agwu et al.,2023), as majority of Tarabans rely on traditional energy sources such as firewood, kerosene, and diesel generators. These alternatives are not only inefficient and environmentally harmful but also hinder economic development by limiting opportunities for entrepreneurship, education, and industrial activities. Addressing this energy deficit is therefore fundamental in order to curb the migration of youth and foster rural development within the state. Solar energy presents a viable and sustainable solution to this challenge. With an average solar radiation of 5.5 kWh/m²/day (Renewable Energy Master Plan, 2019), Taraba State possesses significant potential for harnessing solar power to improve energy access in rural communities. The adoption of decentralized solar energy systems could enhance rural electrification, support micro-enterprises, improve educational facilities, and create employment opportunities, which are key determinants in retaining young

populations in rural areas. This study was conducted to ascertain the potential of the adoption of solar energy as a strategic intervention to mitigate rural-urban migration among youth in Taraba State. While solar energy has been widely recognized as a driver of sustainable development (International Renewable Energy Agency [IRENA], 2022), its impact on migration patterns, particularly within Nigeria's northeast region, remains underexamined. This research seeks to bridge this knowledge gap by providing empirical information on the extent to which solar energy can stimulate rural economic revitalization and enhance living conditions, thereby reducing youth migration. By analyzing the existing solutions to rural-urban migration and their limitations such as agricultural subsidies and rural infrastructure projects this study captures the inadequacies of conventional approaches, particularly their failure to address energy poverty. Unlike previous research, this research focuses on the transformative role of renewable energy, specifically solar power, in advancing economic stability and social well-being in rural communities.

Furthermore, the study employs a mixed-methods approach to assess the effectiveness of solar energy adoption in reducing youth migration. The quantitative analyses evaluate the impact of electrification on migration intentions, while the qualitative data will capture community perspectives on the feasibility and sustainability of solar initiatives. Additionally, key barriers to solar energy adoption such as high costs, limited financing, and low awareness (Emodi & Boo, 2015) are examined, with recommendations formulated to enhance policy interventions and implementation strategies. The study is significant because it contributes to both academic scholarship and policy development. By positioning solar energy as an essential component of rural development, it will provide a replicable model for other regions experiencing similar challenges. Moreover, its findings will inform policymakers and stakeholders on strategies to integrate renewable energy solutions into migration management and rural revitalization efforts.

The study is organized as follows: the Introduction provides an overview of the research context and objectives; the Literature Review examines relevant theory and previous studies; the Methodology outlines the research design and data collection and analysis methods; the Results and Discussion present and analyze the findings; and the Conclusion summarizes key findings and offers recommendations.

Literature Review

Rural-urban migration is a widely studied phenomenon and scholars have always identified an interplay of economic, social, and infrastructural factors that drive population movements (Adepoju, 2020). Push factors such as poverty, unemployment, and inadequate infrastructure create conditions that compel youth to abandon rural communities, while urban centers, with their promise of employment opportunities and modern amenities, act as strong pull factors (Ogunleye & Adeyemi, 2019). In the Nigerian context, these migratory patterns have led to severe urban congestion, straining public services and deepening socio-economic inequalities. Simultaneously, rural depopulation has weakened agricultural productivity, a fundamental pillar of Taraba State's economy. Scholars have increasingly turned their attention to sustainable development strategies that can mitigate these trends, with access to modern energy emerging as a key area of intervention (Bhatia & Angelou, 2015). The role of energy access in reversing rural decline has been well established. Studies have shown that modern energy sources enhance local economic activities, improve education and health services, and elevate overall living standards (Bensch, Peters, & Sievert, 2017). Among various renewable energy options, solar energy has gained prominence as a viable solution for off-grid communities due to its scalability, environmental benefits, and capacity to power productive uses (Aklin et al., 2017). Evidence from global case studies further reinforces its possible impact on rural stabilization. For instance, Chakrabarti and Chakrabarti (2019) found that solar microgrids in India not only reduced dependency on kerosene but also led to a 15% increase in household income, fostering

economic resilience. Similarly, in Kenya, the deployment of solar home systems (SHS) facilitated the growth of small enterprises, which in turn decreased migration intentions among youth seeking better livelihoods in urban areas (Ondraczek, 2013). These outcomes stress solar energy's transformative role in addressing the economic motivations responsible for migration. However, the success of solar energy interventions is contingent upon multiple variables, including affordability, consumer awareness, and government support factors that remain largely deficient when it comes to Nigeria's rural electrification (Ogunleye, 2021). Studies conducted in Pakistan give a comparable perspective; Ali et al. (2020) observed that while solar PV adoption held immense potential for rural electrification, its implementation was hindered by prohibitive costs and a lack of technical expertise. These constraints mirror the challenges faced in many sub-Saharan African nations, where financial barriers and limited policy frameworks continue to impede the scalability of solar initiatives. Theoretically, the Energy Ladder Hypothesis provides a foundational viewpoint on how energy transitions influence socio-economic improvement (Hosier & Dowd, 1987). According to this theory, households progress from traditional biomass fuels such as firewood and charcoal, to more modern, efficient, and sustainable energy sources, such as solar power as their income levels rise. This transition is often linked to improvements in economic productivity, household well-being, and overall quality of life, which in turn influence migration decisions. By facilitating access to cleaner and more efficient energy, solar adoption can enhance rural economic opportunities, promote entrepreneurship, and create a more stable living environment, thereby reducing the motivation for youth to seek better opportunities in urban areas. However, critics have pointed out that this transition is rarely linear; Masera et al. (2000) argue that cultural habits, affordability concerns, and infrastructural deficits often disrupt this progression, preventing rural households from fully adopting modern energy solutions. In the context of Taraba State, where biomass remains the dominant energy source, the potential for solar adoption to shift this trajectory warrants critical examination. Moreover, migration theories such as Lee's (1966) Push-Pull Framework provide a useful perspective for understanding the impact of energy poverty on youth mobility. The framework through a migration-focused lens categorizes the factors that drive individuals away from rural areas (push factors) and those that attract them to urban centers (pull factors). Energy poverty, characterized by unreliable or non-existent electricity access, is a significant push factor, that forces the youth to migrate in search of better infrastructure, employment prospects, and improved living standards. On the other hand, urban amenities such as higher wages, educational opportunities, and better social services act as pull factors that encourage migration. Within this framework, solar energy serves as a critical counterforce by alleviating one of the key push factors. Because it provides stable and 'affordable' electricity, solar adoption improves rural living conditions, advances economic resilience, and reduces dependency on urban centers for basic services, thus mitigating the migration pressure.

By providing decentralized, renewable power solutions, solar energy has the capacity to weaken these push forces, thereby retaining youth in their home communities. Nonetheless, the extent to which solar energy can mitigate migration remains an open empirical question, necessitating a localized investigation into its real-world effects.

Despite its theoretical promise, the large-scale adoption of solar energy in Nigeria faces several structural and economic barriers. Emodi and Boo (2015) mention the high upfront investment costs associated with solar technologies, limited financing options, and inadequate distribution infrastructure as major impediments to its widespread deployment. Furthermore, the integration of youth into renewable energy projects is often overlooked, raising concerns about their exclusion from potential employment and entrepreneurial opportunities within the sector (IRENA, 2022). Without well-planned policies and community-driven initiatives that address these challenges, the optimistic narrative surrounding solar energy's ability to curb rural-urban migration may remain unfulfilled. This study critically engages with the discourse on solar energy's role in mitigating migration by interrogating its practical implications for youth retention in Taraba State. While the prevailing literature emphasizes its developmental benefits, this research seeks to provide empirical evidence on its actual impact,

scrutinizing whether solar adoption translates into tangible livelihood improvements. By bridging the gap between theoretical optimism and on-the-ground realities, this study contributes to a more robust understanding of the relationship between renewable energy and rural sustainability.

Methodology

Research Design

In this study, a mixed-methods approach was employed to capture both quantitative trends and qualitative data on solar energy adoption and migration intentions. This design aligns with the study's exploratory and explanatory objectives, allowing triangulation of data for robust findings (Creswell & Plano Clark, 2018).

Study Area

Taraba State, located in Nigeria's northeast, was selected due to its high rural population (70%), significant youth migration rates, and abundant solar potential. Three LGAs (Ardo-Kola, Bali, and Ussa), one from each of the three senatorial zones in Taraba State, were purposively chosen for their rural dominance and varying levels of solar intervention.

Population and Sampling

The target population comprised youth aged 15–35 in rural Taraba. A sample of 300 youth was selected using stratified random sampling across the three LGAs (100 per LGA), ensuring representation of gender and socio-economic status. Additionally, 20 key informants (village heads, solar vendors, and government officials) were purposively sampled for in-depth interviews to contextualize quantitative data.

Data Collection

Primary data were gathered via structured questionnaires assessing solar access, livelihood impacts, and migration intentions, with a 92% response rate. Semi-structured interviews explored stakeholder perspectives on solar adoption barriers and opportunities. Secondary data from government reports and academic literature supplemented the analysis.

Data Analysis

The quantitative data were analyzed using descriptive statistics (pie charts and bar charts) and logistic regression to determine the relationship between solar adoption and migration intent, conducted using SPSS. Qualitative data on the other hand, underwent thematic analysis using NVivo, identifying recurring themes such as cost, awareness, and youth engagement. The mixed-methods integration ensured comprehensive understandings.

Justification

The mixed-methods design balances statistical rigor with contextual depth, vital for a nascent topic in Taraba. The sample size, though modest, is statistically adequate for regression analysis (Hair et al., 2019), while purposive

sampling of informants leverages expert knowledge. The chosen LGAs reflect diverse rural conditions, enhancing generalizability within the state.

Results and Discussion

Descriptive Findings

In this study, gender dynamics were explored to understand the role of sex in migration decisions among rural youth in Taraba State. The respondents were asked to indicate their gender, which helped to identify possible patterns in migration behavior and the need for gender-specific policy responses. The gender composition of the respondents is presented in Figure 1 below:

Figure 1: Gender Composition of Respondents

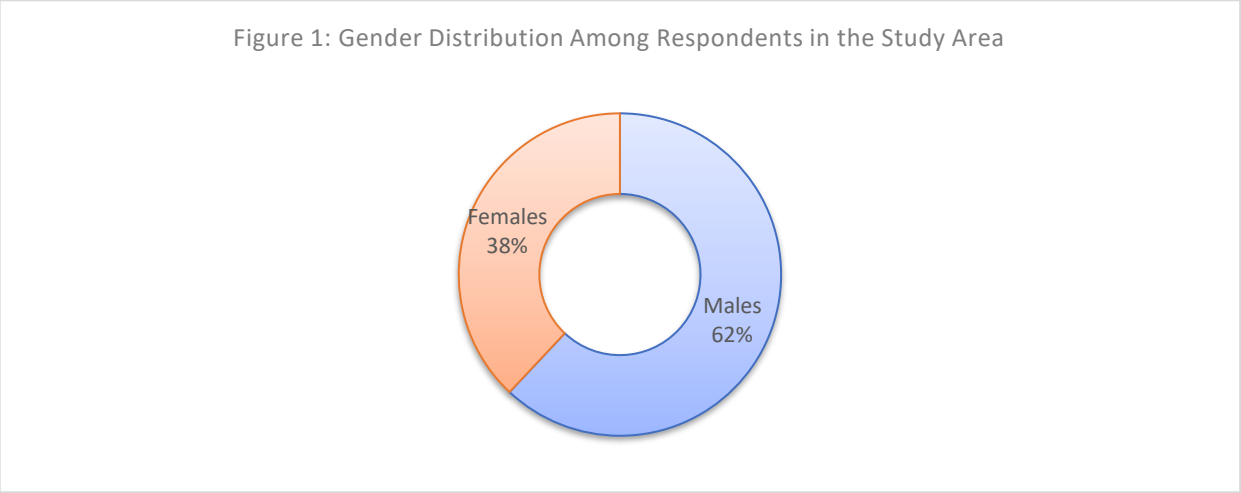
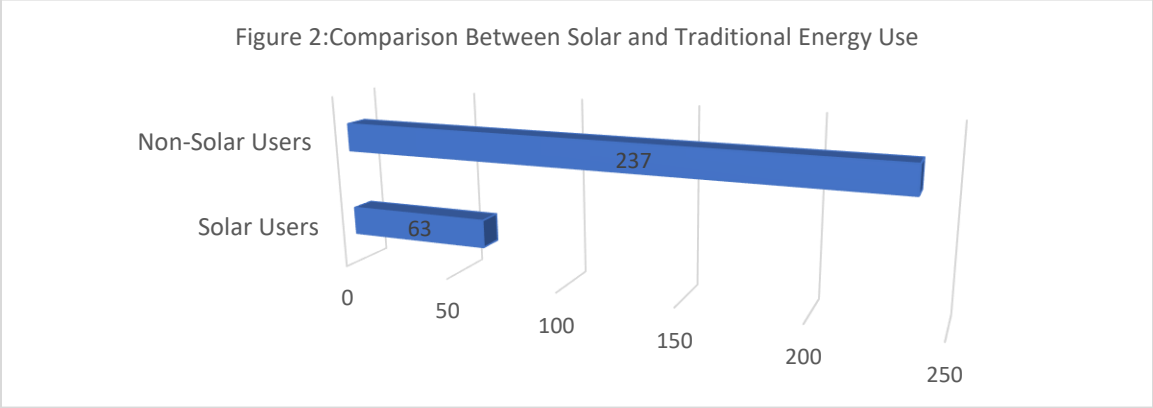


Figure 1 illustrates the gender composition of the respondents of this study. Of the 300 of them, males constituted 62%, while females accounted for 38%. This distribution suggests that rural-urban migration decisions in Taraba State may be male-dominated, aligning with existing migration literature that reveals higher male mobility due to economic responsibilities. However, the significant female representation (38%) accentuates the increasing involvement of women in migration-related economic decisions, necessitating gender-sensitive policy considerations.

Energy Access

Access to energy was a major focus of this study, given its connection to economic productivity and migration behavior. Respondents were asked to indicate their main source of household energy, including whether they used solar or traditional fuels. Their responses are summarized in Figure 2 below:

Figure 2: Type of Energy Sources Used by Respondents

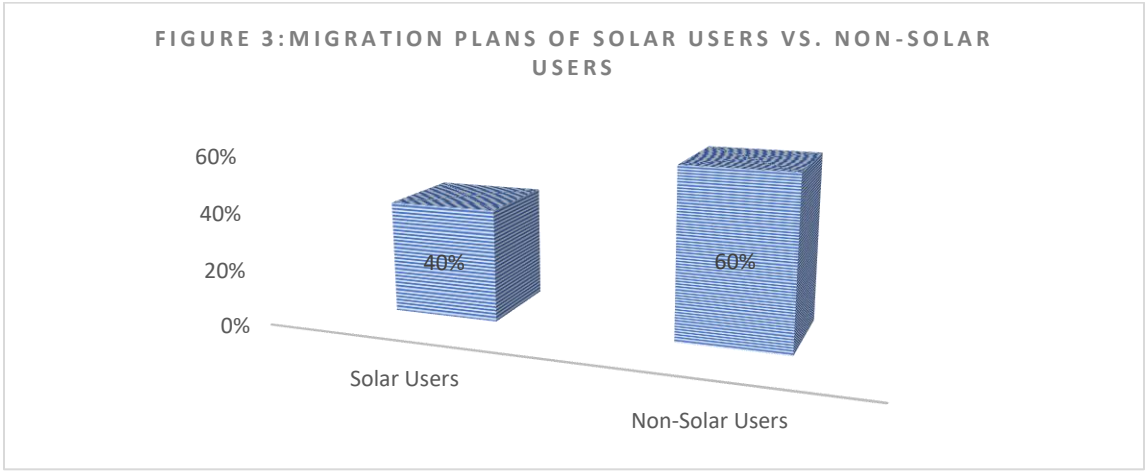


The data in figure 2 reveals the disparity in energy access, as only 21% (n = 63) of respondents were using solar energy, while an overwhelming majority of them (79%- n = 237) remained reliant on traditional fuels such as firewood, kerosene, and diesel generators. This finding shows the persistent issue of poverty of energy in rural Taraba, which limits economic productivity and contributes to out-migration. The low adoption of solar energy may be attributed to factors such as high initial costs, limited awareness, and inadequate policy incentives. Among solar users, 78% (n = 82) reported improved access to lighting and phone charging, and 45% (n = 47) initiated small-scale businesses, such as phone charging stations, tailoring shops, and small retail outlets powered by solar energy. Non-solar users, however, reported higher dependency on biomass (82%, n = 194), contributing to environmental degradation and health issues like respiratory problems.

Migration Intentions

To examine how energy access influences migration intentions, the respondents were asked whether they planned to migrate within the next two years. The responses were analyzed based on their energy source. The result is presented in Figure 3 below:

Figure 3: Migration Intentions by Energy Access



The chart (figure 3) presents a contrast in migration intentions between solar users and non-solar users. Among non-solar users, 68% (n = 161) expressed a strong intent to migrate within the next two years, citing economic hardship and poor living conditions. Conversely, only 40% (n = 42) of solar users intended to migrate, representing a 28% reduction in migration intent associated with access to solar energy. This suggests that improved energy access contributes to rural retention by promoting local economic activities and enhancing the quality of life. The data aligns with theories on sustainable development, and this reinforces the argument that renewable energy can serve as a critical intervention in mitigating rural-urban migration.

Logistic Regression Analysis

To further explore the relationship between solar energy adoption and migration intent, a logistic regression model was employed, controlling for variables such as income, education, gender, and age.

Table 1: Logistic Regression of Migration Intent

Variable	Odds Ratio (OR)	Standard Error	p-value	95% CI
Solar Adoption	0.42	0.15	.008	[0.22, 0.79]
Income (₦/month)	0.78	0.09	.032	[0.62, 0.97]
Education (years)	0.65	0.11	.017	[0.46, 0.92]
Gender (Male = 1)	1.12	0.18	.451	[0.82, 1.53]
Age	0.98	0.03	.672	[0.92, 1.04]

Table 1 presents the results. The data show that solar adoption significantly reduced the likelihood of migration intent (Odds Ratio [OR] = 0.42, p = .008), suggesting that youth with access to solar energy are 58% less likely to plan migration compared to those without. Higher income (OR = 0.78, p = .032) and education levels (OR = 0.65, p = .017) also decreased migration intent, which indicates that economic stability and knowledge play complementary roles. Gender (OR = 1.12, p = .451) and age (OR = 0.98, p = .672) were not significant predictors, signifying that solar energy's impact transcends demographic differences.

Qualitative Data

Thematic analysis of the interviews with key informants revealed three major themes: (1) economic empowerment through solar energy, (2) barriers to adoption, and (3) youth engagement. These themes capture the potential of solar energy to transform rural livelihoods while simultaneously exposing structural and socio-cultural challenges that hinder its widespread adoption.

Economic Empowerment Through Solar Energy

A recurring theme from the interviews was the economic opportunities facilitated by access to solar energy. Respondents emphasized how solar power had enabled them to establish and sustain micro-enterprises, thereby reducing economic pressures that often necessitate migration. One respondent, a rural entrepreneur, recounted: *"I started a phone charging business with my solar panel, and now I save up to ₦5,000 weekly. Before, I had to rely on unreliable fuel generators, which were expensive to maintain."* This finding aligns with previous studies (Chakrabarti & Chakrabarti, 2019; Ondraczek, 2013) that document how solar energy fosters entrepreneurship in off-grid communities by providing a reliable source of electricity for small-scale businesses. In Kenya, Ondraczek

(2013) found that rural youth who leveraged solar power for income-generating activities were significantly less inclined to migrate, mirroring the trend observed in Taraba State. However, this economic potential is not yet fully realized due to structural and financial constraints, as discussed in the next section.

Barriers to Solar Energy Adoption

Despite the evident benefits, several respondents identified significant barriers to solar energy adoption, with financial constraints emerging as the most prominent. The initial investment required to acquire solar home systems (SHS) was widely perceived as prohibitive, with an average SHS cost of ₦80,000. A village head articulated the general sentiment of the rural population:

"Many youths don't know about solar; they think it's for rich people. If the government or NGOs could subsidize the cost, more people would adopt it."

This finding corroborates previous research by Ali et al. (2020), who identified high upfront costs as a major impediment to solar energy diffusion in rural Pakistan. Similarly, Emodi and Boo (2015) found that in Nigeria, limited financing options and a lack of credit facilities constrained solar energy adoption, particularly among low-income households. Beyond the financial barriers, the study also identified a lack of awareness and technical know-how as critical impediments. Many respondents reported limited knowledge of solar energy's benefits and installation processes, suggesting that inadequate sensitization campaigns have hindered adoption. These findings support earlier studies (Ogunleye, 2021; IRENA, 2022) that emphasize the need for targeted awareness programs to increase rural participation in renewable energy solutions.

Youth Engagement in Renewable Energy Initiatives

Another particularly fascinating theme that was common in the interviews was the limited engagement of youth in solar energy initiatives, despite their potential role as key drivers of rural transformation. Respondents noted that there were no structured training programs aimed at equipping young people with the skills to install, maintain, and even manufacture solar components. A solar vendor lamented: *"We need workshops to teach young people how to install and maintain solar systems it would create jobs."* This statement accentuates the broader issue of youth unemployment and underutilization in rural Nigeria. Studies by Bhatia and Angelou (2015) have shown that integrating youth into renewable energy value chains can create employment opportunities, reduce migration pressures, and enhance rural resilience. In India, targeted government initiatives that trained youth in solar energy installation significantly increased adoption rates and economic participation (Chakrabarti & Chakrabarti, 2019).

The findings from Taraba suggest that a similar approach through vocational training programs and incentives for youth-led renewable energy enterprises could amplify the socio-economic benefits of solar adoption. Addressing these challenges would not only enhance rural electrification but also create an avenue for youth-driven economic development, ultimately reducing the push factors driving migration.

Discussion

The findings of this study show that access to solar energy significantly influences rural-urban migration intentions among youth in Taraba State. The data reveal a marked disparity in migration intent between solar energy users and non-users, with solar adopters exhibiting a 28% lower propensity to migrate. This supports the findings of Ondraczek (2013) in Kenya, where solar home systems (SHS) not only improved household energy security but also reduced the urge to migrate. However, while Ondraczek's study emphasized the role of solar energy in

stabilizing rural economies, this study goes further by linking solar adoption to youth retention specifically, stressing a crucial demographic concern in Taraba State. One of the most striking aspects of this research is the role of solar energy in fostering rural micro-enterprises. Nearly half of the respondents who had access to solar energy engaged in small-scale businesses, such as phone charging stations and tailoring shops. This finding agrees with Bhatia and Angelou (2015), who assert that decentralized renewable energy solutions empower rural communities economically. However, unlike Bhatia and Angelou's more generalized conclusions, this study delivers a region-focused standpoint, emphasizing the socio-economic benefits of the adoption of solar within the migratory context of Taraba State's youth. The study suggests that energy availability is not merely an enabler of economic activities but a decisive factor in whether young people choose to remain in rural areas or migrate in search of better opportunities.

Despite these positive findings, there are significant barriers to adoption of solar that persist. The study identifies high initial costs, limited financing options, and a lack of awareness as the primary impediments with the study location. This corroborates the conclusions of Emodi and Boo (2015), who noted similar financial and informational constraints in Nigeria's renewable energy sector. However, while Emodi and Boo focused on general consumer adoption barriers, this study specifically found how these challenges disproportionately affect rural youth, who often lack the capital or technical know-how to invest in solar solutions. Another important dimension of this study is its engagement with theoretical frameworks, particularly the Energy Ladder Hypothesis (Hosier & Dowd, 1987). The study's findings challenge the linearity suggested by the Energy Ladder model, as many rural households in Taraba, despite having access to solar energy, continued to rely on biomass for cooking. This echoes the critique by Masera et al. (2000), who argued that fuel-switching is often non-linear, shaped by cultural habits, affordability, and infrastructural limitations. Consequently, while solar adoption does enhance lighting and small business operations, its impact on comprehensive energy transition remains constrained, necessitating complementary policies that address these broader systemic barriers. Additionally, the findings align with Lee's (1966) Push-Pull Framework, which conceptualizes migration as a balance between push factors (rural deprivation) and pull factors (urban opportunities). The study provides empirical evidence that solar energy weakens key push factors by improving rural living conditions, thereby reducing migration intent. However, it also reveals that while solar access can mitigate migration drivers, it does not entirely eliminate them, as a considerable percentage of solar adopters (40%) still expressed migration aspirations. This suggests that while energy access is crucial, other socio-economic factors such as employment opportunities, educational facilities, and healthcare access must also be enhanced to sustain rural retention comprehensively. Furthermore, qualitative data from interviews provide a deeper understanding of the issues surrounding the utilization of solar energy. Ultimately, the study's findings contribute to the growing body of literature on sustainable rural development by demonstrating that solar energy is not merely an alternative power source but a potential catalyst for socio-economic transformation.

Conclusion

This study set out to investigate the impact of the use of solar energy on rural-urban migration intentions among youth in Taraba State, Nigeria. The findings clearly show that access to solar energy significantly reduces migration propensity, promotes rural entrepreneurship, and enhances local socio-economic stability. Thus, the research successfully achieves its objective by establishing a direct link between the availability of energy and youth retention in rural areas. By presenting a region-specific finding, this study adds to the existing body of knowledge on renewable energy and migration dynamics, particularly within the Nigerian context. While previous research has revealed the economic benefits of regionalized renewable energy, this study extends the discourse by

focusing on its role in mitigating youth migration, an increasingly pressing demographic challenge. The implications of these findings are profound. Policymakers and development practitioners should recognize solar energy not merely as an alternative power source but as a strategic tool for rural stabilization. Expanding solar energy access through subsidies, microfinance schemes, and community-driven awareness programs could considerably enhance rural livelihoods and curb youth outmigration. Additionally, combining solar initiatives with broader rural development policies, such as skills training, job creation, and improved educational and healthcare services, would provide a more holistic approach to sustainable rural retention in Taraba State. Despite the positive contributions of solar energy, barriers such as high initial costs, limited financing options, and cultural resistance to energy transitions remain significant. Therefore, future research should explore innovative financing mechanisms, such as pay-as-you-go solar models or cooperative-based funding, to enhance adoption rates. Additionally, longitudinal studies assessing the long-term socio-economic impacts of solar adoption on migration patterns would provide further findings on its sustained effectiveness.

Declaration

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Conflict of interest: The author declares that there are no conflicts of interest related to this research.

Ethics approval/declaration: All procedures for the conduct of this study were done in accordance with the ethical standards of the institutional and national research guidelines.

Consent to participate: Informed consent was obtained from all individual participants involved in the study. Participants were briefed on the study's objectives, and their participation was entirely voluntary.

Consent for publication: All participants provided consent for their anonymized data to be used in this research and for its findings to be published in academic and public platforms.

Data availability: The datasets generated during and analyzed during the current study are available from the corresponding author on reasonable request.

Author's contribution: The author solely conceptualized, designed, and conducted the research, including data collection, analysis, and manuscript preparation.

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