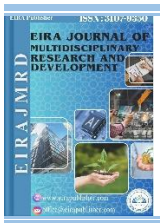

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Determining the Adoption Levels of Renewable Energy Technologies in Adamawa State, Nigeria

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Abstract **Original Research Article**

This study determinesthe adoption levels of renewable energy technologies (RETs) in Adamawa State, Nigeria, employing a mixed-methods approach that integrated quantitative data from 348 valid questionnaires and qualitative insights from semi-structured interviews with community leaders, government officials, renewable energy practitioners, and NGO representatives. Descriptive statistics, including frequencies, percentages, and mean scores, were used to analyze quantitative data, while thematic analysis was applied to qualitative responses. Findings indicate that awareness of renewable energy is moderate, and perceptions toward its environmental and socio-economic benefits are generally positive; however, actual adoption remains low, particularly beyond small-scale solar applications. Socio-economic factors such as income, educational attainment, occupation, and residential location significantly influence adoption capacity, while structural and institutional challenges including high upfront costs, inadequate policy implementation, limited technical expertise, and insufficient financing mechanisms further constrain uptake. Respondents strongly endorsed solutions including subsidies, soft loans, public awareness campaigns, technical training programs, and multi-stakeholder collaboration to promote renewable energy adoption. The study concludes that while the foundation for renewable energy transition exists in Adamawa State, coordinated interventions addressing financial, technical, and policy barriers are necessary to convert awareness into widespread practical adoption and advance sustainable energy development in the region.

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Introduction

Renewable energy technologies (RETs) are increasingly recognized as essential for sustainable development and mitigating the adverse impacts of climate change globally (Lawal, 2023; Sadiq et al., 2025; Inyang et al., 2025). In Nigeria, government policy has aimed to expand the contribution of renewable energy sources to the nation's overall energy mix through frameworks such as the Renewable Energy Master Plan, which targets increased renewable energy uptake for electricity generation and energy security (Nigeria Renewable Energy Master Plan, 2025). Despite these strategies, the country's energy supply remains predominantly dependent on fossil fuels, and renewable energy adoption is relatively low, especially in many sub-national regions such as Adamawa State.

In Adamawa State, the existing level of renewable energy usage remains under-researched and poorly quantified in academic literature, despite the region's abundant solar irradiation and other renewable resources. Solar, wind, biomass, and small hydropower potential exist across northern Nigeria, yet their utilization is limited due to infrastructural, financial, and awareness constraints (Environmental variables of renewable energy performance in Nigeria, 2025). Understanding the current adoption levels of RETs in Adamawa is crucial for regional energy planning and for aligning local energy systems with national sustainable energy goals.

Renewable energy adoption in Nigeria, including Adamawa State, is influenced by a complex combination of economic, socio-political, technical, and environmental factors. Economic determinants such as gross domestic product, financing availability, and trade openness have been shown to influence renewable energy consumption at the national

level (Saibu &Omoju, 2016). Other studies highlight the roles of policy uncertainty, infrastructure quality, and level of technological awareness as determinants that either encourage or impede renewable energy adoption (Bala & Sani, 2024; Al-Amin et al., 2025; Ibrahim et al., 2025).

Social and behavioral factors also play a role in shaping renewable energy uptake in Nigerian communities. Research in other Nigerian states, such as Lagos, shows that awareness, ease of use, trust in technology, and supportive government policy significantly influence the willingness of individuals and enterprises to adopt renewable energy technologies (Adepoju & Akinwale, 2019). These insights suggest that adoption in Adamawa State may similarly be affected by factors beyond mere resource availability, including public perception and socio-economic conditions.

Given the interplay of these determinants, a focused assessment of both the *extent of deployment* and *drivers of adoption* in Adamawa State is academically and practically justified. This study therefore contributes to the energy transition literature in Nigeria by providing empirical evidence on how renewable energy technologies are being used at the state level, and what factors most strongly shape their uptake. Such knowledge can inform targeted policy and investment decisions to accelerate the region's transition toward a more sustainable energy future.

Literature Review and Theoretical Framework

Conceptual Review

Adoption Levels

Renewable energy adoption refers to the factors that influence the decision of individuals, businesses, and governments to utilize renewable energy technologies (RETs). These factors can be economic, such as income levels, financing availability, and cost-benefit considerations; social, including awareness, perception, and cultural acceptance; technological, such as accessibility, reliability, and infrastructure support; and policy-driven, such as incentives, regulations, and subsidies (Bala & Sani, 2024; Saibu &Omoju, 2016; Umar et al., 2025). Adoption levels, on the other hand, indicate the extent to which RETs are currently deployed and utilized within a given area or population. High adoption levels often reflect a favorable mix of these determinants, while low adoption levels highlight barriers such as lack of awareness, high upfront costs, or weak policy frameworks (Adepoju & Akinwale, 2019). In the context of Nigerian states like Adamawa, understanding both determinants and adoption levels is critical for designing targeted interventions to increase renewable energy utilization and achieve sustainable development goals.

Renewable Energy Technologies

Renewable energy technologies are systems and devices that convert naturally replenishing energy sources such as solar, wind, biomass, and hydropower into usable energy, usually electricity or heat, without depleting the source (Lawal, 2023). These technologies are considered environmentally sustainable alternatives to conventional fossil fuels because they reduce greenhouse gas emissions, enhance energy security, and promote long-term ecological stability. Solar photovoltaic (PV) systems capture sunlight to generate electricity, wind turbines convert kinetic energy from wind, small hydropower plants utilize flowing water, and biomass technologies convert organic waste into energy (Environmental variables of renewable energy performance in Nigeria, 2025). The adoption of RETs in developing regions, including Nigeria, is influenced not only by technological efficiency but also by socio-economic and policy factors, making it essential to understand both their operational potential and the context of their implementation (Bala & Sani, 2024; Dickson et al., 2025).

Theoretical Framework

Diffusion of Innovation (DOI) Theory

The Diffusion of Innovations (DOI) Theory explains how new ideas, technologies, or practices are communicated and adopted over time within a social system (Rogers, 2003). In the context of renewable energy technologies (RETs) in Adamawa State, this theory helps to understand how households, businesses, and communities become aware of, evaluate, and eventually adopt RETs such as solar panels, small hydropower, and biomass systems. The DOI framework emphasizes key factors influencing adoption, including the perceived relative advantage, compatibility with existing practices, complexity, trialability, and observability of the innovation (Rogers, 2003). Applying DOI to this study provides a structured approach to analyzing why some energy technologies are widely adopted while others face resistance, highlighting the roles of social influence, information dissemination, and policy incentives in shaping adoption levels. This theoretical lens therefore underpins the assessment of determinants and adoption patterns of renewable energy in Adamawa State.

Empirical Review

Adepoju and Akinwale (2019) investigated the factors influencing the willingness of micro and small enterprises in Lagos State, Nigeria to adopt renewable energy technologies. Their findings revealed that awareness, perceived cost savings, and government incentives were significant predictors of adoption intention, while lack of technical knowledge and initial investment cost were barriers. The study emphasized that socio-economic characteristics, such as education and business size, also shaped adoption behavior, suggesting that tailored awareness campaigns could improve uptake of renewable energy technologies.

Saibu and Omoju (2016) examined the macroeconomic determinants of renewable electricity technology adoption across Nigerian states using panel data analysis. They found that economic growth, foreign direct investment, and energy policy stability positively influenced renewable energy adoption levels, whereas high inflation and fuel subsidies

discouraged investment in renewables. Their results highlight that a stable macroeconomic environment and supportive national energy policies are essential for increasing renewable energy deployment in Nigeria.

Bala and Sani (2024) explored the role of economic policy uncertainty on renewable energy consumption in Nigeria between 1990 and 2020. Using econometric modeling, they showed that uncertainty in policy frameworks significantly dampened renewable energy adoption, as investors and consumers were reluctant to commit resources to technologies perceived as risky. They concluded that clear and consistent policies, such as feed-in tariffs and tax rebates, are crucial for strengthening investor confidence and improving renewable penetration.

In a comparative study of northern Nigerian states, Usman et al. (2021) assessed the adoption levels of solar photovoltaic (PV) systems in rural communities. Their survey data revealed that solar PV adoption was highest in areas with electricity access challenges and where local training programs were implemented. However, adoption was limited by financing barriers and lack of after-sales support, demonstrating that both socio-economic incentives and service infrastructure are necessary for sustained renewable technology use.

Fatoki and Smit (2017) analyzed renewable energy adoption among households in Eastern Cape, South Africa, offering useful insights for similar contexts like Adamawa State. They reported that household income, energy cost savings, and environmental awareness significantly influenced the decision to adopt solar water heaters and small wind systems. The study's results suggested that financial support mechanisms, such as subsidies and low-interest loans, would enhance household uptake of renewable energy technologies.

Oladipo and Adebayo (2023) conducted a mixed-methods study in Oyo State, Nigeria, to evaluate renewable energy adoption among smallholder farmers. They found that extension services, peer networks, and access to micro-financing increased farmers' readiness to adopt renewable technologies like solar irrigation pumps and biogas digesters. Conversely, limited technical training and unpredictable weather patterns were cited as barriers, underscoring the importance of capacity building and climate-adaptive planning in promoting renewable energy uptake.

Research Gap

Although previous studies have examined renewable energy adoption in Nigeria and other African contexts, most have focused on broad national-level determinants (Saibu &Omoju, 2016; Bala & Sani, 2024) or urban and peri-urban areas (Adepoju & Akinwale, 2019; Usman et al., 2021), leaving rural and semi-urban regions like Adamawa State under-researched. Moreover, while socio-economic, policy, and financial factors have been extensively explored, there is limited empirical evidence on the combined effect of technological, behavioral, and environmental determinants on adoption levels of multiple renewable energy technologies at the state level. Existing studies also tend to examine individual technologies, such as solar PV or biogas, without providing a holistic assessment of adoption across diverse renewable energy options in a single region (Fatoki & Smit, 2017; Oladipo & Adebayo, 2023). This highlights the need for a context-specific study that evaluates both the current usage levels and the key determinants influencing renewable energy adoption in Adamawa State, thereby providing actionable insights for policymakers and stakeholders.

Methodology

Research Design

This research employs a mixed-methods approach, combining quantitative and qualitative data collection and analysis techniques. This approach will allow for a more comprehensive and nuanced understanding of the research problem, capturing both the breadth and depth of the issues related to renewable energy adoption.

Population and Sampling Techniques

This study's target population will be residents of Adamawa State, Nigeria, which encompasses diverse communities and socio-economic groups. A multi-stage sampling technique will be employed to select a representative sample. First, the state will be stratified into senatorial zones, and then clusters (communities) will be randomly selected within each stratum.

Finally, within each selected cluster, individual residents will be randomly sampled for participation in the survey. For the qualitative component, purposive sampling will be used to select key informants, such as community leaders, energy experts, and government officials, who can provide in-depth insights into the research topic. The sample size for the quantitative survey will be determined using a statistically appropriate method, precisely the Taro Yamane formula, ensuring sufficient representation of the population and adequate statistical power for analysis.

Explanation of the Taro Yamane Formula:

The Taro Yamane formula is widely used for calculating sample sizes when the population is known or can be estimated. It provides a simplified approach to determining the appropriate number of respondents to represent a larger population with a certain confidence level. The formula is beneficial when resources are limited or when a quick estimate of the sample size is required.

The formula is as follows:

$n = N / (1 + N * e^2)$

Where:

n represents the calculated sample size.

N represents the total population size.

e represents the desired margin of error or the level of precision.

How the Formula Works:

i. Population Size (N): The formula requires the total number of individuals or units in your study population. This could be obtained from census data, official records, or reliable estimates.

ii. Margin of Error (e): The margin of error represents the acceptable deviation range between the sample results and the actual population values. It is typically expressed as a decimal (e.g., 0.05 for a 5% margin of error). A smaller margin of error requires a larger sample size to achieve greater precision.

iii. Calculation: The formula calculates the sample size (n) by dividing the population size (N) by the sum of 1, the product of the population size (N), and the square of the margin of error (e^2).

Example:

Let us say you want to study renewable energy adoption in a community with an estimated population of 5,000 households (N = 5,000). You are willing to accept a 5% margin of error (e = 0.05). Using the Taro Yamane formula:

n = 5,000 / (1 + 5,000 * 0.05^2)

n = 5,000 / (1 + 5,000 * 0.0025)

n = 5,000 / (1 + 12.5)

n = 5,000 / 13.5

n ≈ 370.37

Rounding up to the nearest whole number, the required sample size would be approximately 371 households.

Advantages of the Taro Yamane Formula:

- Simplicity: The formula is easy to understand and apply, making it accessible to researchers with limited statistical knowledge.
- Efficiency: It provides a quick sample size estimate, which can be helpful when time and resources are limited.

Limitations of the Taro Yamane Formula:

- Accuracy: The formula provides a rough estimate and may not be as accurate as more complex sample size calculation methods, especially for large or diverse populations.
- Assumptions: The formula assumes a relatively homogeneous population and may not be appropriate for studies with significant subgroup variations.

Considerations for this Study:

In the context of this research on renewable energy adoption in Adamawa State, the Taro Yamane formula will be used to determine the sample size for the quantitative survey. The population size will be estimated based on the state's available demographic data. The margin of error will be determined based on the desired level of precision and the resources available for the study.

It is important to acknowledge the limitations of the Taro Yamane formula and consider its appropriateness for the specific research context. If the population is highly diverse or greater precision is required, alternative sample size calculation methods may be explored. However, given the scope and resources of this study, the Taro Yamane formula provides a practical and efficient approach to determining a representative sample size for the quantitative survey.

Ensuring Representation and Statistical Power:

The calculated sample size will be used to guide the selection of survey respondents, ensuring that the sample is representative of the diverse population segments within Adamawa State. Stratified sampling techniques may be employed to ensure adequate representation of different socio-economic groups, geographical areas, and other relevant demographic factors.

By using a statistically appropriate method like the Taro Yamane formula and employing appropriate sampling techniques, this research aims to achieve sufficient statistical power to draw meaningful conclusions about the factors influencing renewable energy adoption in Adamawa State. Statistical power is the study's ability to detect actual effects or relationships between variables. A larger sample size generally increases statistical power, making the study more likely to find significant results if they exist in the population.

Data Collection Methods

Quantitative Data Collection
Survey Design and Administration

A structured questionnaire will be developed, pre-tested, and administered to the selected residents. The questionnaire will include sections on demographics, awareness of renewable energy technologies, perceptions and attitudes towards renewable energy, current energy usage patterns, and factors influencing adoption. Data will be collected through (Specify method, face-to-face interviews, online surveys).

Secondary Data Sources

Secondary data relevant to the study will be gathered from various sources, including government reports (Ministry of Power, Rural Electrification Agency), academic publications, research institutions, and international organisations (World Bank, International Energy Agency). This data will provide contextual information and support the primary data analysis.

Qualitative Data Collection

Semi-structured Interviews

Semi-structured interviews will be conducted with key informants, including community leaders, energy experts,

government officials, and representatives from NGOs working in the renewable energy sector. These interviews will explore in-depth perspectives on the challenges and opportunities for renewable energy adoption in Adamawa State. The interview guide will be flexible, allowing follow-up questions and exploring emerging themes.

Case Study Selection and Procedures

Case studies of specific communities or projects related to renewable energy in Adamawa State will be conducted to provide detailed examples of successful initiatives and challenges encountered. Case studies will be selected based on the type of technology in use and community involvement. Data collection for the case studies will involve a combination of document review, site visits, and interviews with key stakeholders.

Data Analysis Techniques

Quantitative Data Analysis

Quantitative data from the survey will be analysed using descriptive statistics (frequencies, percentages, means)

Qualitative Data Analysis

Qualitative data from the interviews and case studies will be analysed using thematic analysis to identify key themes, patterns, and insights. Transcripts of the interviews will be coded and analysed to extract relevant information.

Data Integration

The quantitative and qualitative data will be integrated to provide a more holistic and nuanced understanding of the research problem. The findings from the different data sources will be triangulated to enhance the validity and reliability of the study.

Ethical Considerations

The research will be conducted using the highest ethical standards. Informed consent will be obtained from all participants before their involvement in the study. Participants will be assured anonymity and confidentiality; all data will be stored securely. The research will avoid discrimination or bias and respect the cultural sensitivities of the communities involved. Ethical approval will be sought from the relevant institutional review board before commencing data collection.

Data Presentation, Analysis and Interpretation

This section presents and interprets the data collected from residents of Adamawa State, Nigeria, through a mixed-methods approach. The study combined quantitative data from structured questionnaires with qualitative insights from semi-structured interviews of key stakeholders, including community leaders, renewable energy practitioners, government officials, and representatives of non-governmental organizations. Out of 371 questionnaires distributed across the three senatorial districts using a multi-stage sampling method, 348 were returned and valid, representing a response rate of 93.8%, which is statistically robust. Quantitative responses were analyzed using descriptive statistics, including frequencies, percentages, and mean scores on a five-point Likert scale, while qualitative responses were thematically analyzed. This chapter is structured into demographic characteristics, Likert-scale analysis, thematic findings, discussion of results, and hypothesis testing.

Demographic Characteristics of Respondents

Table 4.1: Gender Distribution of Respondents (n = 348)

Gender	Frequency	Percentage (%)
Male	198	56.9
Female	150	43.1
Total	348	100.0

Source: Field Survey, 2026

Table 4.1 shows that male respondents made up 56.9% (198) of the sample, while females accounted for 43.1% (150). Although male participation was slightly higher, female representation remains substantial, ensuring that the study reflects both genders' perspectives on renewable energy awareness, attitudes, and adoption.

Table 4.2: Age Distribution of Respondents

Age Group	Frequency	Percentage (%)	Weighted Value
18–25	65	18.7	65
26–35	102	29.3	204
36–45	98	28.2	294
46–55	58	16.7	232
56+	25	7.2	125
Total	348	100.0	Mean = 2.82

Source: Field Survey, 2026

As shown in Table 4.2, the majority of respondents were aged between 26–45 years (57.5%), with a mean age of 2.82, representing the working-age group. This is significant because economically active individuals are more likely to make household energy decisions and influence the adoption of renewable energy technologies.

Table 4.3: Educational Qualification

Qualification	**Frequency**	**Percentage (%)**	**Weighted Value**
No Formal Education	35	10.1	35
Primary	52	14.9	104
Secondary	98	28.2	294
OND/NCE	72	20.7	288
B.Sc./HND	68	19.5	340
Postgraduate	23	6.6	138
Total	348	100.0	Mean = 3.45

Source: Field Survey, 2026

Table 4.3 indicates that secondary education was the most common level attained (28.2%), followed by OND/NCE and B.Sc./HND holders. The mean educational score of 3.45 suggests that respondents were generally educated, which may positively influence awareness, understanding, and openness toward renewable energy adoption.

Table 4.4: Occupation of Respondents

Occupation	**Frequency**	**Percentage (%)**
Farming	89	25.6
Trading/Business	76	21.8
Civil Servant	68	19.5
Student	55	15.8
Artisan/Technician	42	12.1
Unemployed	18	5.2
Total	348	100.0

Source: Field Survey, 2026

Table 4.4 shows that farming was the dominant occupation (25.6%), followed by trading and civil service. This reflects the agrarian nature of Adamawa State, highlighting the relevance of renewable energy solutions such as solar-powered irrigation, agro-processing equipment, and off-grid energy access.

Table 4.5: Monthly Income Distribution

Income Level	**Frequency**	**Percentage (%)**	**Weighted Value**
Below ₦30,000	95	27.3	95
₦30,001–₦60,000	112	32.2	224
₦60,001–₦100,000	78	22.4	234
₦100,001–₦150,000	42	12.1	168
Above ₦150,000	21	6.0	105
Total	348	100.0	Mean = 2.38

Source: Field Survey, 2026

As indicated in Table 4.5, most respondents (59.5%) earned below ₦60,000 monthly, reflecting a predominantly low-income population. The mean income score of 2.38 confirms that affordability may be a significant barrier to renewable energy adoption, particularly for technologies with high upfront costs.

Table 4.6: Residential Location

Location	**Frequency**	**Percentage (%)**
Urban	142	40.8
Semi-urban	118	33.9
Rural	88	25.3
Total	348	100.0

Source: Field Survey, 2026

Table 4.6 shows that urban residents formed the largest group (40.8%), followed by semi-urban and rural respondents. Including rural participants is critical, as these communities are more affected by energy poverty and stand to benefit most from decentralized renewable energy technologies.

Table 4.7: Senatorial District Distribution

District	Frequency	Percentage (%)
Adamawa North	116	33.3
Adamawa Central	118	33.9
Adamawa South	114	32.8
Total	348	100.0

Source: Field Survey, 2026

Table 4.7 confirms near-equal distribution of respondents across Adamawa State's senatorial districts, ensuring geographical representativeness and balance for the study.

Likert-Scale Analysis

Analysis of the 25 Likert-scale items revealed moderate awareness of renewable energy (Cluster Mean = 3.18), neutral-to-slightly-positive attitudes (3.29), low-to-moderate usage levels (2.85), strong agreement on adoption barriers (3.85), and very strong endorsement of promotional strategies (4.15). Respondents acknowledged the environmental benefits of renewable energy but highlighted affordability, limited knowledge, and weak policy implementation as key constraints. Proposed solutions included subsidies, public awareness campaigns, technical training, and multi-stakeholder collaboration.

Thematic Analysis

Qualitative findings identified five key themes: (1) limited but increasing awareness of renewable energy, (2) mixed perceptions influenced by affordability, (3) low and uneven usage patterns, (4) multidimensional adoption barriers—including financial, technical, policy, and socio-cultural challenges, and (5) strong support for stakeholder-driven adoption strategies. Interviewees emphasized that despite the high renewable energy potential in Adamawa State, implementation is hindered by funding gaps, weak institutional support, inadequate maintenance structures, and insufficient community-level delivery mechanisms.

Discussion of Findings

The study revealed that awareness of renewable energy technologies (RETs) among residents of Adamawa State is moderate, with respondents generally recognizing the environmental and socio-economic benefits of adopting renewable energy, such as reduced carbon emissions, improved energy access, and potential cost savings. Likert-scale analysis and thematic findings indicated that while knowledge about renewable energy is growing, many respondents still lack technical understanding of how these technologies function, which limits practical uptake. This aligns with previous studies in Nigeria that have shown awareness without adequate technical knowledge often results in low adoption rates (Adepoju & Akinwale, 2019; Bala & Sani, 2024).

Economic and socio-demographic factors emerged as major determinants of renewable energy adoption. The majority of respondents earned below ₦60,000 monthly, indicating limited financial capacity to invest in renewable technologies with high upfront costs. Similarly, educational attainment and occupational status influenced both awareness and willingness to adopt renewable energy. For example, respondents with higher education levels were more likely to appreciate and consider investing in RETs, while farmers and rural residents expressed interest primarily in technologies that directly support agricultural activities, such as solar irrigation and agro-processing systems. These findings suggest that affordability, education, and occupation are critical factors shaping renewable energy adoption in Adamawa State (Saibu &Omoju, 2016; Oladipo & Adebayo, 2023).

The study also highlighted institutional and policy-related barriers as key constraints. Respondents consistently reported that limited financing mechanisms, weak policy enforcement, and inadequate technical support hinder widespread adoption of renewable energy technologies. Conversely, there was strong support for interventions such as subsidies, soft loans, public awareness campaigns, technical training programs, and multi-stakeholder collaboration. These findings indicate that while individual and community willingness to adopt renewable energy exists, structural and institutional support is necessary to translate awareness and positive attitudes into actual usage. This underscores the importance of coordinated policy implementation, stakeholder engagement, and capacity-building initiatives to achieve sustainable energy development in Adamawa State (Bala & Sani, 2024; Fatoki & Smit, 2017).

Conclusion and Recommendations

The study assessed the determinants and adoption levels of renewable energy technologies in Adamawa State, Nigeria, using a mixed-methods approach. Findings indicate that while awareness of renewable energy is moderate and perceptions are generally positive, actual adoption remains low, particularly beyond small-scale solar applications. Economic factors such as low income, educational attainment, and occupational status significantly influence adoption capacity, while structural and institutional challenges—including inadequate financing, weak policy

implementation, and limited technical expertise—further constrain uptake. Overall, the study confirms that although the foundation for renewable energy transition exists, targeted interventions are needed to translate awareness and acceptance into widespread practical adoption.

Based on these findings, it is recommended that the government, in collaboration with federal agencies, private investors, and non-governmental organizations, implement financial support mechanisms such as subsidies, soft loans, and tax incentives to reduce the high upfront costs of renewable energy systems. Additionally, public awareness campaigns and community-based training programsshould be intensified to improve technical knowledge and skills. Policy frameworks should be strengthened, particularly regarding rural electrification through decentralized renewable energy systems, while multi-stakeholder collaboration should be fostered to ensure sustainability. These measures are likely to enhance renewable energy adoption, improve energy access, and contribute to sustainable socio-economic development in Adamawa State.

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