Clean Cooking Energy Transition: Feasibility Study on Biogas Adoption Among Low-Income Households in Anambra State

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ABSTRACT

This study investigates the feasibility of adopting biogas stove technology as a clean cooking energy alternative among low-income households in Anambra State, Nigeria. In rural communities in Anambra State, households commonly utilize various cooking energies, including firewood, charcoal, kerosene, and LPG (Liquefied Petroleum Gas) among others. Using a survey design, data were collected from 251 respondents across select communities. Findings reveal that although LPG is a common fuel source, a significant number of households still rely on kerosene and charcoal, underscoring ongoing energy poverty and environmental health risks. This implies that persistent use of polluting fuels despite LPG access suggests economic fragility and vulnerability to energy insecurity. While awareness of biogas technology is moderate (61.8%), a sizable proportion remains uninformed. Key factors influencing adoption include perceived safety, financial and technical support, and evidence of successful use in rural settings. Notably, 87.3% of respondents expressed willingness to adopt biogas, conditional on these concerns being addressed. Major barriers to transition include safety apprehensions, lack of familiarity, and cost constraints. The study highlights the need for targeted awareness campaigns, financial incentives, and community demonstration projects to facilitate a just and inclusive clean energy transition in Anambra State.

Keywords: Biogas adoption, clean cooking energy, low-income households, energy transition, Anambra State.

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INTRODUCTION

Biogas is a type of clean gas produced by anaerobic decomposition of organic matter. It is defined by Nidal et al (2022) as a modern form of bio-energy that can be produced through anaerobic digestion or fermentation of a variety of biomass sources. Biogas production involves biological breakdown of biodegradable materials such as manure, sewage, municipal waste, green waste, plant materials and energy crops. Biogas primarily consists of methane and carbon (IV) oxide with a small amount of hydrogen and trace of hydrogen sulphide. These gases can be combusted with oxygen in the air which is about 21 per cent hence allowing biogas to be used

as fuel.

Biogas is considered as one of the most potential renewable energy resources and the most environmental-friendly energy source. The major drive for research in this field is the need to diversify clean cooking energy source due to high cost of LPG and to overcome the negative environmental, economic and women and children's health implication for incessant use of firewood.

In the past, solid biomass, (wood), has been recognized to be used majorly by the rural dwellers. However, the present LPG price hike has inclusively dragged many urban and semiurban dwellers to resort to the use of wood, charcoal and kerosene as alternatives. This has not only increased the environmental stress, but heightened the health and economic consequences. The energy conversion and combustion of solid biomass (wood and charcoal) impose serious adverse health implications. Kerosene which most people often use, in addition to its high cost, equally delivers serious negative health implication as a result of its combustion pattern. This reality pushed many to adopt LPG as cooking energy.

LPG/Cooking gas is symbolic, as it represents a product that many Nigerians, especially those living in urban and semi-urban areas of Anambra state adopted as cooking energy. The continuous rise in the price of LPG in recent times, exemplifies everything wrong with Nigeria's economy and why the economic handlers should make a deliberate effort for diversification and sustenance of cooking energy. According to the estimation by the World Health Organization, household air pollution (HAP) accounts for up to 3.2 million premature deaths each year which mostly affects women and children, (IEA, IRENA, UNSD, World Bank, WHO, 2022). This is more than 4,000 deaths per day, more than half of them are children under five years of age. 85% of these deaths are attributed to wood while the remaining part is caused by coal. This means that indoor air pollution associated with wood use is directly responsible for more deaths than malaria, almost as many as tuberculosis and almost half as many as HIV/AIDS, (WHO, 2006).

Scenarios like this prompted United Nations to declare the need for change in the global energy system, (United Nations, 2021). UN Sustainable Development Goals 7, (SDG 7), urged the need to transition this population to Clean Energy Cooking Service, which aims to ensure access to affordable, reliable, sustainable, and modern energy for all, (United Nations General Assembly 2015). Therefore, the proposed study on feasibility study on biogas stove adoption among low-income women in Anambra State represent an important research problem.

From the foregoing, the following research questions are posed to guide the study;

1. What are the current cooking energy sources used by low-income households, and what challenges do they face?
2. What is the level of awareness of small-scale biogas cook stoves among low-income women?
3. What are the key factors influencing the adoption of biogas cooking energy in low-income communities?
4. To what extent are the low-income households willing to adopt biogas?
5. What barriers affect the transition to biogas technology in the context of low-income, climate-vulnerable settings?

Literature Review

Energy Poverty and Gender Inequality

Energy poverty, particularly in developing countries, disproportionately affects women,

especially those in low-income households. Globally, over 2.6 billion people rely on traditional biomass for cooking, which contributes significantly to indoor air pollution, adverse health outcomes, and time poverty for women (Midrap et al, 2023). In Nigeria, women often bear the burden of fuel collection and cooking, increasing their vulnerability to health issues and limiting their opportunities for education and income generation (Global Subsidies Initiative–IISD, BIDS, IRADe & Spaces for Change, 2019; Adekoya et al, 2023). This dynamic underscore the gendered nature of energy poverty, where access to modern energy services can significantly improve women's well-being and socio-economic status.

Biogas Technology and Its Applications

Biogas is a clean, renewable energy source produced from the anaerobic digestion of organic waste such as animal dung, kitchen waste, and agricultural residues. Its applications range from household cooking to electricity generation and heating (Kabeyi & Olarewaju, 2022). In low-income settings, biogas stoves offer a viable alternative to firewood and charcoal, reducing dependency on biomass and associated health risks. Studies have shown that biogas adoption can significantly reduce indoor air pollution and fuel collection time, thereby enhancing household health and productivity (Sean et al, 2014; Kimutai et al., 2025). In rural South Africa and Kenya, biogas initiatives have proven effective in promoting sustainable energy transitions among marginalized communities (Kimutai et al., 2025; Rasimphi et al, 2024).

Factors Influencing Adoption of Clean Cooking Technologies

Several factors influence the adoption of clean cooking technologies, including affordability, accessibility, cultural acceptability, and awareness. Rogers' diffusion of innovation theory suggests that perceived benefits, ease of use, and social influence significantly impact technology adoption (Rogers, 2003). In Nigeria, adoption of biogas technology is often hindered by high initial costs, lack of technical knowledge, and limited access to support services (Nwankwo et al., 2024). However, targeted awareness campaigns and subsidies have been shown to improve adoption rates among low-income users (Ani et al., 2024, An, 2013).

Socio-cultural and Economic Barriers to Energy Transition

Socio-cultural norms and economic realities often serve as barriers to energy transition in developing contexts. In many Nigerian communities, traditional cooking practices are deeply rooted in cultural identity, making change difficult (Chukwurah et al., 2025; Akintan et al, 2018). Moreover, economic constraints such as low income, lack of financing, and competing household priorities impede the adoption of alternative energy solutions (Adekoya et al, 2023; Nwankwo et al, 2024). Gender norms also restrict women’s decision-making power in energy-related matters, limiting their ability to switch to cleaner technologies (Raman et al., 2025).

Policy Frameworks Supporting Clean Energy in Nigeria

Nigeria has made various policy efforts to support the transition to clean energy. The National Renewable Energy and Energy Efficiency Policy (NREEEP, 2015) emphasizes the promotion of renewable energy technologies, including biogas. Additionally, the Nigeria Energy Support Programme (NESP), implemented with support from GIZ, aims to improve energy access in rural areas. Despite these initiatives, gaps in policy implementation, funding, and institutional coordination hinder widespread adoption (Regina & Mohammad, 2019; Nwankwo et al., 2024). Strengthening policy frameworks, providing financial incentives, and building capacity at the community level are essential for successful energy transitions.

METHODS

Research design and study area

This study employs a descriptive cross-sectional survey design, utilizing a structured questionnaire to gather quantitative data from a broad sample of respondents at a single timepoint. This approach is particularly effective for identifying current perceptions, practices, and patterns within a population without manipulating variables, thereby offering a snapshot of prevailing conditions relevant to the research objective. It facilitates the analysis of associations between socio-demographic factors and outcomes such as biogas awareness or adoption intent. The cross-sectional design is widely recommended in energy-access and public health research for its practicality and robustness in large community studies.

The research was conducted in selected Local Government Areas (LGAs) of Anambra State with a focus on rural and peri-urban communities where traditional cooking methods are prevalent, and biogas has potential viability. Specifically, this study was conducted in Orumba South, Aguata and Aniocha LGAs in Anambra State.

Population, Sample and sampling technique

The target population includes low-income women and their households, particularly those responsible for cooking and household energy decisions. The exact figure of the population is not known since there is no available data on the number of low-income earners in rural areas in Anambra State.

Respondents are 18 years and above, residents of the selected LGAs for at least one-year, primary cooks or household heads responsible for energy-related decisions. Households currently using biogas as their primary cooking source and respondents unable to give informed consent are excluded. A total of 251 respondents were randomly selected from the three LGAs. The descriptions of the study sample are found in the tables 1 and 2

Table 1

Sample description

		LGA			
		Aguata	Aniocha	Orumba South	Total
Gender	Female	48	61	77	186
	Male	31	19	15	65
Total		79	80	92	251

Table 2

Monthly household income level of respondents across the three LGAs

		LGA			
		Aguata	Aniocha	Orumba South	Total
Income	Above N100,000	14	2	0	16
	Below - N10,000	1	13	1	15
	N10,000 - N30,000	16	25	22	63
	N30,001 - N50,000	12	12	28	52
	N50,001 - 70,000	22	16	30	68
	N70,000 - N100,000	14	12	11	37
Total		79	80	92	251

Data collection and analysis

A structured questionnaire was administered, comprising both closed and open-ended questions. The instrument covers five sections, namely: Socio-economic characteristics; Current energy practices; Awareness and perceptions of biogas, Willingness to adopt biogas and finally, an open-ended response on barriers and suggestions. This questionnaire was put in a google form. Six research assistants were trained and deployed to collect data using google form. The research assistants speak the native language of the respondents and could translate the items in their native language to elicit response seamlessly.

Quantitative data was analyzed using SPSS version 25. Descriptive statistics (frequency, mean, standard deviation), Cross-tabulations (e.g., awareness vs. education level) were used for data analysis.

RESEARCH RESULTS

The outcomes of the data analysis are presented under the following themes based on the research questions.

The current cooking energy sources used by low-income households

The outcomes of the data analyses on cooking energy sources used by low-income household as follows:

Table 3

Primary cooking energy source by low-income households

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Charcoal	10	4.0	4.0	4.0
	Electricity	7	2.8	2.8	6.8
	Firewood	65	25.9	25.9	32.7
	Kerosene	11	4.4	4.4	37.1
	Liquefied Petroleum Gas (LPG)	151	60.2	60.2	97.2
	Others	7	2.8	2.8	100.0
	Total	251	100.0	100.0	

Table 3 indicate that most respondents, (151) 60.2 %, currently rely on LPG as major source of their cooking energy while the remaining (100) 39.8% rely on other sources of energy. Specifically, 4% (10) use charcoal, 2.8% (7) use electricity, 25.9% (65), kerosene 4.4% (11), and others 2.8% (7). The implication of this is that a good number of the people still depend on charcoal, firewood and kerosene with their dire attendant health implications. Also, there is great doubt of the sustainability of the use of LPG due to its incessant price increase. A look at the monthly income of household (Table 2) alludes to this position that LPG use is not sustainable by these households.

Level of awareness of small-scale biogas cooking energy

The outcomes of the data analyses on cooking energy sources used by low-income household as follows:

Table 4

Level of awareness of biogas cooking energy

	I've heard about biogas	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	96	38.2	38.2	38.2
	Yes	155	61.8	61.8	100.0
	Total	251	100.0	100.0	

Table 4 reveals that 38.2% (96) of the respondents have not heard of biogas as a cooking energy source while 61.8 % (155) of the respondents are aware. Although the number of those who are aware of biogas cooking energy are more in number, the number who are not aware is substantial. This underscores the need for sensitization of the rural populace on the potency of biogas cooking energy source.

Key factors influencing the adoption of biogas cooking energy in low-income communities

Table 5

Influencing factor of biogas adoption in low-income communities

Key factor	Frequency	Percent	Valid Percent	Cumulative Percent
Assurance of safety	74	29.5	29.5	29.5
Availability of financial support (loans, subsidies)	92	36.7	36.7	66.1
Availability of technical support and training	56	22.3	22.3	88.4
Demonstration of successful usage in the community	29	11.6	11.6	100.0
Total	251	100.0	100.0	

Table 5 indicates shows the factors that influence the possible adoption of biogas cooking energy by low-income households as their primary cooking energy source. The factors noted are assurance of safety, availability of financial support, technical support and demonstration of successful usage in rural communities. Specifically, 74 (29.5%) of the respondents raised assurance of safety as an influencing factor. Others are availability of financial support (e.g., loans, subsidies), 92 (36.7%), availability of technical support, 56 (22.3%), and demonstration of successful usage in the rural communities, 29 (11.6). Based on this, it means that most people will reject biogas if it is not affordable. This may largely be due to their financial capacity which is determined by their income (Table 2).

The willingness to adopt biogas cooking energy among low-income households

Table 6

Willingness to adopt biogas as primary source of cooking energy

	Frequency	Percent	Valid Percent	Cumulative Percent
No	32	12.7	12.7	12.7
Yes	219	87.3	87.3	100.0

Willingness to adopt biogas as primary source of cooking energy

	Frequency	Percent	Valid Percent	Cumulative Percent
No	32	12.7	12.7	12.7
Yes	219	87.3	87.3	100.0
Total	251	100.0	100.0	

Table 6 is the result of analysis of data collected from the respondents on their willingness to adopt biogas cooking energy. Majority, 219 (87.3%), of the respondents are willing to adopt biogas cooking energy while 32 (12.7%) are unwilling. Although the level willingness appears high, it is not unconditional. The willingness is hinged on the hopes that their various concerns are addressed (see Table 7).

Barriers that affect transition to biogas technology in the context of low-income, climate-vulnerable settings

Table 7

Barriers affect the transition to biogas technology in the context of low-income

Biogas adoption concerns	Frequency	Percent	Valid Percent	Cumulative Percent
High initial cost of installation	43	17.1	17.1	17.1
Safety concerns	160	63.7	63.7	80.9
Unfamiliarity with the technology	48	19.1	19.1	100.0
Total	251	100.0	100.0	

Table 7 reveals the potential barriers to transitioning to biogas technology as pointed out by the respondents. The concerns raised borders on cost, safety and technical know-how. Top among the concerns is safety, 160 (63.7%), followed by unfamiliarity with biogas technology, 48 (19.1%) while high-cost concerns is 43 (17.1%). This implies that transitioning will be inhibited if these concerns are not addressed.

DISCUSSION

Current Cooking Energy Sources and Associated Challenges

The study reveals that 60.2% of low-income households in Anambra State rely primarily on Liquefied Petroleum Gas (LPG), while the remaining 39.8% use alternative energy sources including charcoal (4%), electricity (2.8%), kerosene (25.9%), and others (2.8%). These findings highlight a mixed reliance on both modern and traditional fuels, reflecting the concept of "fuel stacking"—a phenomenon where households use multiple fuels rather than transitioning fully to clean energy (Yadav et al, 2021).

Despite the increased use of LPG, the sustainability of this option is questionable given the frequent price hikes in Nigeria (Musa et al., 2023; Agbai & Aigbedion, 2024). Households with limited income such as those of urban origin (as shown in Table 2) may be forced to revert to cheaper, hazardous fuels such as kerosene and firewood, thereby exacerbating exposure to indoor air pollution and associated health issues like respiratory diseases (Yadav et al., 2021; Atuyambe et al, 2024). This underscores the urgent need for affordable and sustainable energy alternatives, especially for economically vulnerable populations.

Awareness of Biogas Cook Stoves

The level of awareness of biogas cook stoves is moderately high, with 61.8% of

respondents aware of biogas technology while 38.2% have not heard of it. Although the awareness level is promising, the sizeable proportion of those unaware indicates a significant information gap. Awareness plays a critical role in technology adoption (Roger, 2003; Moshi & Matto, 2024). In rural and peri-urban communities, lack of exposure to clean energy technologies often results in resistance to new innovations due to uncertainty and unfamiliarity (Streimikiene et al, 2024). This finding reinforces the necessity for public awareness campaigns and educational outreach to increase familiarity and trust in biogas as a viable clean energy source.

Factors Influencing Adoption of Biogas Technology

Four primary factors were identified as influencing the potential adoption of biogas: assurance of safety (29.5%), financial support (36.7%), technical support (22.3%), and demonstration of successful use in similar communities (11.6%). These results align with the Technology Acceptance Model (TAM), which emphasizes the role of perceived usefulness and ease of use in influencing adoption decisions (Musa et al, 2024; Marikyan & Papagiannidis, 2025).

The demand for financial and technical support highlights the economic and infrastructural challenges prevalent in low-income settings (Regina & Mohammad, 2019; Rasimphi et al, 2024). Households are more likely to adopt biogas if there is assurance of safety, access to microfinance schemes, and technical guidance. This is consistent with findings from other low-income regions where adoption of clean energy technologies is hampered by affordability and lack of technical capacity (Rasimphi et al, 2024; Regina & Mohammad, 2019).

Demonstration of biogas use in similar localities can serve as a trust-building measure. Pilot projects that allow potential users to observe the benefits and functionality of biogas technology have been shown to significantly boost uptake in comparable settings (Sovacool et al., 2015).

Willingness to Adopt Biogas

An impressive 87.3% of respondents expressed willingness to adopt biogas cooking energy. This demonstrates a positive predisposition towards clean energy transitions, indicating that with the right enabling conditions, the shift from traditional fuels to biogas is feasible. However, this willingness is conditional—dependent on whether the barriers identified in the study are addressed. This aligns with the findings of Kimutai et al (2025), who emphasized that expressed willingness must be supported by practical facilitators such as affordability, accessibility, and technical know-how for actual adoption to occur.

Barriers to Biogas Transition

Key barriers identified include concerns over safety (63.7%), unfamiliarity with biogas technology (19.1%), and high cost (17.1%). These reflect the typical constraints faced in clean energy adoption in developing countries. Safety concerns are particularly significant, especially among female users who are traditionally responsible for cooking and managing household energy use (UNDP, 2013). Fear of accidents and lack of knowledge about biogas systems can create resistance, even when other factors are favorable.

Unfamiliarity with the technology suggests a need for user-centered design and inclusive training programs. If users are not confident in handling the technology, sustained adoption is unlikely (Wang et al., 2020; Kulugomba et al., 2025). High cost remains a persistent obstacle, reiterating the need for subsidies or financing mechanisms to lower initial investment thresholds for poor households.

In all, the study reflects that although low-income households in Anambra State are willing to transition to biogas technology, the transition is challenged by financial constraints, limited awareness, and safety concerns. Addressing these barriers through policy interventions, stakeholder engagement, and community education is essential for a sustainable clean cooking energy transition.

Limitations and Future Research Directions

Despite the valuable insights provided by this study, several limitations must be acknowledged. First, the research employed a cross-sectional survey design, which captures respondent perceptions and intentions at a single point in time. This limits the ability to draw causal inferences or observe actual behavioral changes over time. Longitudinal or experimental studies could offer a more dynamic understanding of adoption behavior, sustainability, and user satisfaction with biogas technology.

Second, the study relied on self-reported data, which are susceptible to biases such as social desirability or recall inaccuracies. For example, respondents might overstate their willingness to adopt biogas technology due to perceived expectations from the researchers. Incorporating observational methods or triangulating data with energy usage records would enhance validity.

Third, the geographical scope was confined to selected communities within Anambra State. Although this region provides relevant insights, the findings may not be generalizable to other Nigerian states with different socio-economic, cultural, or infrastructural contexts. Broader, multi-state studies are needed to capture regional disparities and understand context-specific drivers and constraints.

Finally, while the study identified financial and technical support as major adoption factors, it did not quantitatively assess the economic feasibility or cost-benefit analysis of biogas stove usage compared to other energy options. Future studies should model affordability thresholds and perform techno-economic assessments to inform policy and investment decisions.

Conclusion

This study explored the feasibility of adopting biogas stoves as a clean cooking energy alternative among low-income women in Anambra State. The findings reveal that while a considerable number of households currently rely on LPG, a significant portion still uses kerosene, charcoal, and other biomass fuels, which pose serious environmental and health risks. Awareness of biogas technology is relatively high, but notable knowledge gaps remain. Crucial factors influencing adoption include financial support, safety assurance, technical assistance, and evidence of successful implementation in similar communities.

The study further establishes a strong willingness among respondents to adopt biogas technology; however, this willingness is contingent upon overcoming barriers such as safety concerns, lack of familiarity with the technology, and affordability. These results underscore the importance of policy interventions, community-level sensitization, and pilot demonstration projects aimed at increasing trust and capacity for the uptake of clean cooking technologies. A multi-stakeholder approach involving government agencies, NGOs, and private sector actors will be essential to scale adoption and drive sustainable energy transition in vulnerable communities.

Recommendations

1. Given that 38.2% of respondents had never heard of biogas as a cooking energy source, and even among those aware, significant misconceptions exist regarding safety and usability, targeted awareness campaigns are vital to reach low-income households.
2. There should be subsidy provided by the government for a given period for effective transition.

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Conflict of Interest

There is no conflict of interest among the authors.

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