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EVALUATING ADOPTION AND OPERATION OF AN ON-CAMPUS BIOGAS ENERGY SYSTEM AT DAVID UMAHI FEDERAL UNIVERSITY OF HEALTH SCIENCES, UBURU, NIGERIA

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Abstract

The growing global focus on sustainable energy has renewed interest in biogas, especially in developing regions facing energy poverty and weak organic waste management. This study examines the feasibility, awareness, and adoption potential of campus-based biogas systems among food vendors, cleaners, and security staff at David Umahi Federal University of Health Sciences, Uburu, and its host community. A mixed-method design combined questionnaire, focus group discussions, and statistical analysis to generate primary data from forty-seven respondents. Findings show that although many participants (70.2%) were aware of biogas technology, only 48.9% demonstrated adequate understanding of its operation. However, a large majority (97.9%) expressed willingness to adopt biogas, provided affordability, safety, and reliability are assured. Key barriers include safety concerns (29.8%), perceived maintenance difficulty (23.4%), and high initial costs (19.1%). Chi-square tests revealed significant relationships between awareness, gender, location, and willingness to participate in co-ownership arrangements ($p < 0.05$). Overall, the study indicates that biogas is a viable and sustainable energy option for the university setting. It recommends targeted capacity building, technical support mechanisms, and pilot-scale installations to improve acceptance, strengthen user confidence, and promote long-term adoption of campus-based biogas technology. These actions will enhance environmental stewardship and strengthen local energy resilience significantly.

Keywords: Biogas, Energy, Economy, Feasibility, Sustainability, Waste

1.0 INTRODUCTION

Biogas technology, defined as the anaerobic digestion of organic biomass to produce methane-rich gas for energy generation, has been widely recognized as a viable renewable energy option in developing countries where energy insecurity and poor waste management systems persist. Biogas production has evolved from early European innovations (Metcalf et al., 1979) to small-scale applications across Asia and Africa (Ghimire P, 2013). In Nigeria, biogas adoption has gained increasing scholarly attention due to chronic electricity shortages, heavy reliance on fossil fuels and traditional biomass, rising fuel costs, and escalating environmental concerns (Ani et al., 2024). Nigeria's energy mix remains dominated by fossil fuels and hydropower, with renewable biomass resources - particularly biogas - remaining largely underexploited despite their proven technical and environmental advantages (Nwankwo et al., 2024).

Several studies underscore Nigeria's substantial biogas potential arising from abundant agricultural residues, municipal solid waste, livestock manure, and institutional organic waste streams (Akinbami et al., 2001; Mohammed et al., 2017). Reviews of biomass utilization consistently identify biogas as one of the least developed renewable energy technologies in Nigeria, despite its capacity to simultaneously address waste management, energy access, and greenhouse gas mitigation (Okafor et al., 2022). These findings are reinforced by regional African studies showing that biogas adoption remains far below potential due to institutional and socio-economic constraints rather than technological infeasibility (Amigun et al., 2008).

Within Nigerian tertiary institutions, organic waste generation from hostels, cafeterias, staff quarters, and laboratories presents a consistent feedstock base suitable for medium- to large-scale biogas systems. Empirical estimates indicate that Nigerian tertiary institutions could collectively generate over 177,000 m³ of biogas daily, equivalent to approximately 221 MWh of energy, if waste-to-energy systems were properly implemented (Owoyale et al., 2020). Similar feasibility studies conducted in universities in southwestern Nigeria confirm that campus-based hybrid energy systems can significantly reduce dependence on diesel generators while lowering institutional energy costs (Olatomiwa et al., 2016).

Despite this potential, biogas adoption within tertiary institutions remains limited. Studies attribute this gap to poor waste segregation practices, inadequate technical capacity for digester operation and maintenance, insufficient funding, and weak institutional commitment to renewable energy deployment. Institutional inertia and the perceived reliability of diesel-powered generators further discourage long-term investment in biogas infrastructure (Oyedepo et al., 2014). Moreover, Nigeria's national renewable energy policies acknowledge biomass broadly but fail to provide explicit mandates or incentives for biogas deployment in educational institutions (Nwankwo et al, 2024)

At the community level, adoption studies consistently report low awareness and utilization of biogas technology across rural, peri-urban, and urban settings. A household survey in Lagos State, Nigeria found that fewer than 15% of respondents were aware of biogas as a viable energy option, with cost, lack of information, and perceived complexity cited as major deterrents (Fadayini et al., 2015). Similar findings have been reported in studies conducted in Ogun, Oyo, and Edo States, where socio-economic status, education level, and access to technical support significantly influenced adoption decisions(Ogbomida et al., 2025) (Akinwale et al., 2014).

Economic barriers dominate the literature on biogas adoption in Nigeria and across sub-Saharan Africa. High upfront capital costs, limited access to credit, absence of subsidy frameworks, and long payback periods discourage households and institutions from investing in biogas systems (Farrukh et al., 2024) (Kabir et al., 2013). These challenges are compounded by the relative affordability and availability of conventional fuels such as firewood, kerosene, and liquefied petroleum gas (Ozoh et al., 2018). Energy access and environmental sustainability remain pressing challenges in developing economies. The dependence on firewood, charcoal, and fossil fuels has exacerbated deforestation and greenhouse gas emissions, threatening public health and ecological balance (Ukpai et al., 2012). Within this context, biogas production through anaerobic digestion (AD) offers a circular solution: converting organic waste into a renewable energy resource while mitigating

environmental pollution (Agbede et al., 2020).
Social and cultural factors further shape adoption outcomes. Several studies report resistance to the use of waste-derived energy due to cultural perceptions, sanitation concerns, and limited trust in new technologies (Mwirigi et al., 2014). In Nigeria, public perception studies indicate that inadequate awareness campaigns and weak extension services have limited community acceptance of biogas systems (Ayoade et al, 2017). Education and demonstration projects are therefore identified as critical drivers of adoption (Bond et al., 2011).
Policy and institutional analyses emphasize that Nigeria's slow biogas diffusion reflects weak regulatory support and fragmented governance structures. Comparative African studies show that countries with dedicated biogas policies, subsidy schemes, and institutional coordination-such as Rwanda and Kenya - have achieved higher adoption rates (Kemausuor et al., 2018) (Woldemichael et al., 2022).Nigerian scholars therefore advocate for the integration of biogas into national energy planning, including fiscal incentives, institutional mandates for public facilities, and public-private partnerships (Akinbomi et al., 2014).
Technological studies further demonstrate that system performance depends on feedstock composition, digester design, and operational management. Research confirms that co-digestion of food waste, animal manure, and agricultural residues improves methane yield and system stability (Alfa et al., 2014; Owamah et al., 2014). African case studies also reveal that decentralized, small-scale digesters are particularly suitable for community applications, while institutional settings benefit from larger centralized systems (Parawira W, 2017). Overall, the literature demonstrates that biogas technology represents a largely untapped yet highly viable solution for sustainable energy generation and waste management in Nigerian tertiary institutions and local communities.

In rural communities like Uburu, Ebonyi State, Nigeria, waste management and energy affordability pose dual challenges. Institutions such as the David Umahi Federal University of Health Sciences (DUFUHS) can serve as catalysts for technology demonstration and community empowerment through localized renewable energy systems. This study investigates the operationalization and perception of biogas systems within DUFUHS and its host community, focusing on practical strategies for overcoming adoption barriers among key user groups.

2.0 METHODOLOGY

2.1 Theoretical Framework

The study adopts the Technology Acceptance Model (TAM) and Diffusion of Innovation Theory (Rogers E, 2003) to explain user behavior toward biogas adoption. Awareness, perceived usefulness, and perceived safety influence intention to adopt, while social influence and institutional support accelerate diffusion. Figure 1 illustrates the core stages of anaerobic digestion: hydrolysis, acidogenesis, acetogenesis, and methanogenesis, leading to biogas and biofertilizer outputs.

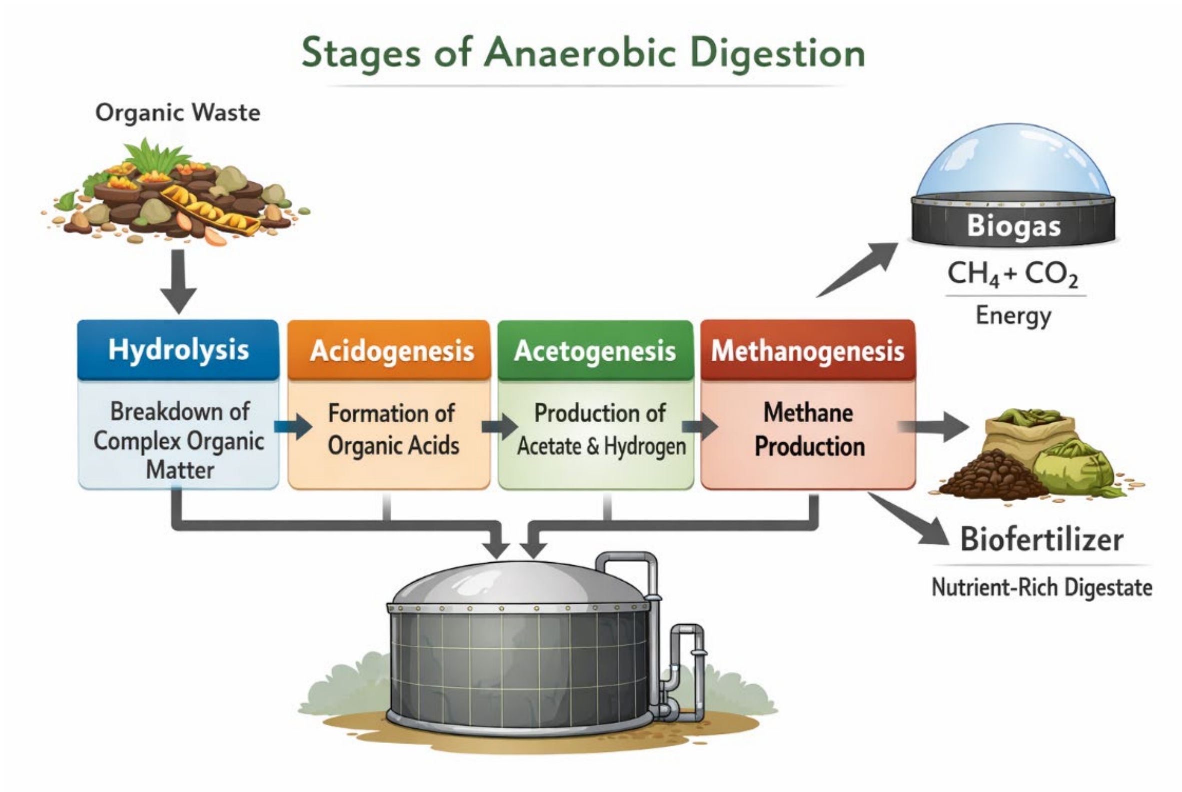

Figure 1: Biogas production (Google.com)

2.2 Study Area and Population

The study was conducted at the David Umahi Federal University of Health Sciences (DUFUHS), a new federal institution in Ebonyi State, Nigeria. The site offers abundant organic waste from cafeterias, hostels, and staff quarters. Target participants were food vendors, cleaners, and security staff-groups with daily energy needs and waste generation activities.

2.3 Research Design and Data Collection

A mixed-methods approach was employed:

i. **Quantitative Survey:** 47 structured questionnaires captured demographics, awareness, perceptions, and willingness to adopt biogas within the university community.

ii. **Qualitative Interviews:** Semi-structured interviews with stakeholders explored barriers and cultural perceptions.

iii. **Focus Group Discussions:** Group sessions identified socio-cultural factors influencing adoption.

2.4 Data Analysis

Descriptive statistics and chi-square (χ^2) tests were performed using Excel and SPSS to identify associations among key variables (e.g., awareness vs. gender; fuel type vs. health issues). Significance was tested at $p < 0.05$.

2.5 Ethical Considerations

Ethical approval was obtained from the DUFUHS-UREC Methodological Advisory Subcommittee. Participants provided informed consent and were briefed on Environmental Safety and Data Confidentiality.

3.0 RESULTS AND DISCUSSION

3.1 Demographic Overview

Of 47 respondents, 53.2% were aged 31 - 40, 57.4%

female, and 72.3% worked within DUFUHS premises. The majority (61.7%) had over three years of work experience, ensuring stable engagement in biogas-related initiatives.

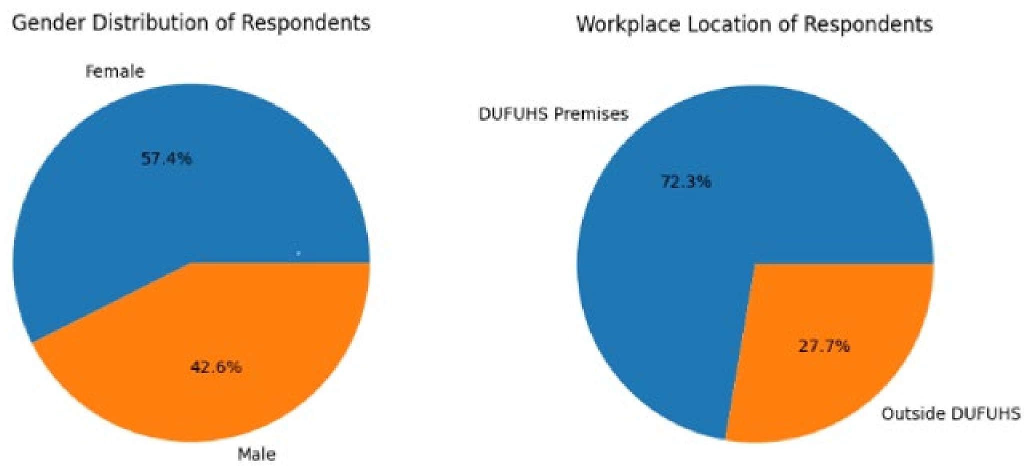

Figure 2: Demographic overview of respondents

3.2 Awareness and Practices

About 70.2% had heard of biogas, but only 48.9% understood its production process. Current cooking fuels included LPG (57.4%), firewood (17.0%), and charcoal (17.0%), confirming ongoing biomass dependence. Waste disposal predominantly involved open dumping (42.6%) or municipal bins (46.8%).

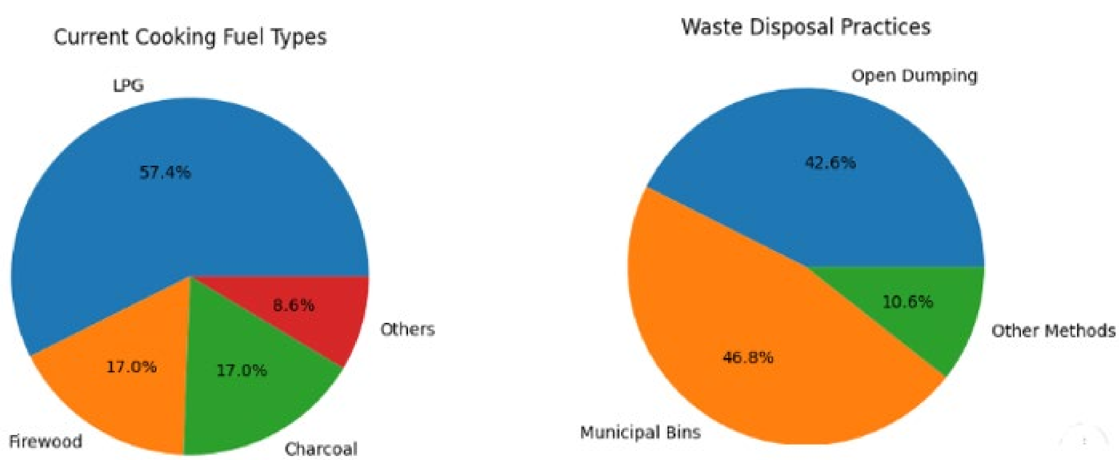

Figure 3: Graphical outlook of awareness and practices

3.3 Perceptions and Challenges

A vast majority (97.9%) expressed interest in adopting biogas systems if cost savings and safety could be assured. Safety concerns (29.8%) and maintenance issues (23.4%) emerged as the top deterrents. High fuel costs (48.9% reported "always" high) and inconsistent supply (31.9%) reinforced the motivation for alternative energy.

3.4 Adoption Support and Co-Ownership

Over half (57.4%) were willing to co-own biogas systems within shared facilities. Training (42.6%) and reliable technical support (25.5%) were prioritized over financial subsidies. Adoption likelihood was remarkably high - 70.2% indicated they were “very likely” to use biogas if available.

3.5 Inferential Analysis

The inferential analysis reveals statistically significant relationships among the key variables examined, underscoring important socio-demographic and contextual factors influencing biogas awareness, health outcomes, and adoption potential. The association between awareness and gender is significant (χ^2 = 12.39, p = 0.00043), indicating that awareness of biogas technology varies meaningfully across gender groups, which aligns with existing evidence on gendered energy roles. Location exhibits a highly significant relationship with waste disposal practices (χ^2 = 48.36, p = 8.4×10^{-8}), suggesting that spatial context strongly shapes waste management behavior and, by extension, biogas feedstock availability. Similarly, the relationship between fuel type and health complaints is highly significant (χ^2 = 91.70, p = 1.6×10^{-11}), providing robust statistical support for the link between traditional fuel use and adverse health outcomes. Finally, the strong association between co-ownership willingness and location (χ^2 = 56.46, p = 1.6×10^{-11}) indicates that communal or institutional settings may be particularly conducive to shared biogas systems. Overall, the results validate the relevance of socio-economic and locational factors in shaping biogas adoption dynamics.

Table 1: Descriptive statistics of key variables

Variables Tested	χ^2	p-value	Significance
Awareness vs Gender	12.39	0.00043	Significant
Location vs Waste disposal	48.36	8.4×10^{-8}	Highly significant
Fuel type vs Health complaints	91.70	1.6×10^{-11}	Highly significant
Co-ownership vs Location	56.46	1.6×10^{-11}	Highly significant

3.6 Discussion

The predominance of female respondents highlights the *gender relevance in biogas adoption*, as women are often the primary users of household energy and thus stand to benefit most from reduced smoke exposure and lower energy costs. This is in tandem with other research in rural energy transitions which similarly found that gender influences willingness to adopt biogas, with women more likely to support adoption due to their responsibility for daily cooking and fuel collection (Uhunamure et al., 2019). This is further emboldened by the fact that reduced exposure to indoor biomass smoke is linked with improved respiratory outcomes for women when biogas replaces traditional fuels such as wood or charcoal, underscoring the health co-benefits of adoption (Dohoo et al., 2012).

Despite relatively high awareness of biogas’s advantages, *low technical understanding* persists among many potential users, suggesting an *information-implementation gap* that structured training programs could address. Previous studies across Africa have noted that inadequate technical training and after-installation support limit effective system use and confidence in the technology (Kulugomba et al., 2024).

Economic motivation remains central: nearly half of respondents' report fuel cost pressures that make cleaner alternatives like biogas appealing. Economic analyses across Sub-Saharan biogas studies also show that expected fuel savings and reduced household expenditures can drive interest, but high upfront costs and lack of financing remain barriers. This result is similar to that of a study in Cameroon, for example, where it was found that willingness to pay for small-scale biogas was influenced by economic viability perceptions, with extension services and subsidies identified as key motivators for adoption (Ketuama et al., 2024). Health challenges associated with indoor smoke further justify the transition to cleaner energy. Women have noted that biogas not only shortens cooking time but reduces indoor air pollution and related health burdens, providing evidence of tangible health improvements at the household level(Schoeber et al., 2020).

The *willingness to co-own systems* suggests that communal biogas plants could serve as viable dissemination models, especially in institutional or semi-urban settings where individual ownership cost and maintenance demands may be prohibitive. Such shared or cooperative arrangements can pool resources, spread technical know-how, and foster ownership, addressing common barriers documented in African biogas contexts (Kalina et al., 2022).

Furthermore, *safety fears and perceived maintenance complexity* mirror findings in previous African studies where technical capacity and institutional trust were crucial for scaling. In many regions, lack of ongoing technical support and maintenance services discourages continued use and leads to system abandonment after initial installation attempts (Kulugomba et al., 2024). Integrating *hands-on technical training*, clear safety protocols, and *accessible aftercare services* will be essential to building user confidence and long-term viability. Pilot demonstrations and community engagement initiatives can also demystify the technology and showcase its practical benefits, encouraging both uptake and sustained use over time (Sari et al., 2022).

Overall, findings support the hypothesis that **institutional demonstration projects**-particularly within universities-can accelerate community-level diffusion of clean energy technologies by linking education, research, and service.

3.6.1 Risk-Benefit and Environmental Considerations

Potential risks such as flooding, temperature fluctuations, and slurry mismanagement can be mitigated through site elevation, waterproofing, and controlled waste reuse. Environmental benefits include:

i. Reduction of Open Dumping and Methane emissions.

ii. Conversion of Digester Slurry to Biofertilizer.

iii. Decline in Deforestation from reduced firewood demand.

iv. Improved Indoor Air Quality and Occupational Health.

3.6.2 Policy Implications and Recommendations

a. **Institutional Integration:** DUFUHS management should include biogas within its energy diversification policy, alongside solar and wind sources.
b. **Capacity Building:** Continuous training for users and technicians to ensure safe operation and maintenance.
c. **Pilot Demonstration Units:** A functioning campus biogas system can serve as a live learning model and community sensitization tool.
d. **Financial Incentives:** Government or donor subsidies could reduce installation costs for low-income users.
e. **Public-Private Partnerships:** Encourage co-ownership and small business models for scaling adoption.

4.0 CONCLUSION

This study demonstrates that biogas technology holds strong potential for sustainable waste-to-energy conversion at DUFUHS and its host community. Awareness and willingness are high, yet practical adoption depends on technical training, cost reduction, and perceived safety. A community-based, university-led biogas initiative can simultaneously advance energy security, public health, and environmental sustainability-positioning DUFUHS as a model for institutional circular economy practice in Nigeria.

Author Contributions

All authors contributed to the conceptualization, fieldwork, analysis, and manuscript preparation. Corresponding author supervised data integrity and manuscript revisions.

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Conflict of Interests

The authors declare no conflict of interests..

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