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EVALUATING SOCIAL ACCEPTANCE OF BIOGAS TECHNOLOGIES FOR SUSTAINABLE ENERGY TRANSITION IN NIGERIA: CASE STUDY OF RURAL COMMUNITIES IN BENIN CITY, EDO STATE

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ABSTRACT

The development of biogas technologies and their deployment in energy-deficient urban and peri-urban settlements of developing countries is essential for achieving key Sustainable Development Goals (SDGs). In alignment with its Energy Transition Plan targeting net-zero emissions by 2060, the Nigerian government recognizes waste-to-energy technology as a timely solution for mitigating climate change, addressing municipal solid waste (MSW) challenges, and providing energy for household and commercial use. However, biogas deployment in Nigeria remains limited, with social acceptance as a significant constraint. This study evaluated the effects of social acceptance on biogas deployment in Benin City, Nigeria. Data were collected from 420 systematically and purposively sample respondents on their perceptions of biogas technologies. Social acceptance indices included economic factors (household income and investment opportunities), technological complexity, socio-political acceptance (government support), market readiness, and cultural/religious attitudes toward feedstock such as cattle rumen and poultry droppings. Findings revealed that social media was the primary information source on waste-to-energy technologies, followed by seminars which focus on waste-to-energy. LPG was the main household cooking fuel in Benin City, followed by biomass, while electricity ranked lowest due to cost and power supply inconsistency. Fossil fuel attractiveness and availability were major factors influencing fuel choice. Awareness of waste-to-energy technologies ranged from low to moderate. Key barriers to biogas deployment included economic concerns, technological complexity, need for government support, and cultural resistance to feedstock handling. The study recommends intensified training and sensitization programs to promote biogas technologies within local contexts.

Keywords: *Energy insecurity, waste-to-energy, biogas technology, social acceptance, level of awareness,*

1. INTRODUCTION

Energy availability and affordability are the main driving forces of the development of human society as well as economic development and growth. According to Esen and Bayrak (2017), energy consumption per capita of a country is regarded as an important indicator of economic development. In terms of direct effects on livelihood, energy access is crucial for cooking and food processing (natural gas/coal/biomass), lighting, refrigeration, cooling, communication (electricity), powering household appliances (electricity), heating (biomass, kerosene, electricity), transportation, and small-scale agriculture (mechanized farming). As most developing countries of the World have set out action plans towards the attain the UN SDGs of zero poverty and provision of clean energy, reducing the disproportionate burden of diseases among women, children, and infants who are the most at risk of energy poverty, access to clean energy is inextricably linked to achieving these goals (Our World in Data team 2023; Gabrah et al., 2023). Unfortunately, despite the important role energy plays in economic development and household livelihood sustainability, energy insecurity is still a huge challenge for most communities in the developing countries as well as Sub-Sahara Africa (Mayer 2022, Ajibola et al., 2024; International Energy Agency, 2024; Filho et al., 2024).

Household energy insecurity (HEINS) has been defined as the lack of access to adequate, affordable, reliable, acceptable, and clean sources of energy for a healthy and sustainable livelihood, and this insecurity poses a challenge to several sub-groups within households; particularly women, infants, and children in developing countries (Boateng *et al*., 2020). Jiang (2020) also defined energy insecurity as a constraint in access and affordability of modern forms of energy, especially electricity. Communities in the rural areas of developing countries are the worst hit by energy poverty as these communities are geographically located in remote and/or difficult-to-reach areas without access to technology and essential infrastructure services. Zaman *et al*., (2020) reported that hundreds of millions of poor rural households, who live in remote and difficult-to-reach areas, are still without access to energy. Globally, it is estimated that about 85 percent of 789 million people in non-electrified households live in rural areas (UN, 2020) and are known as the "last mile" of universal energy access (Gómez and Silveira, 2015; Tomei, 2020). Poor energy access in the communities undermines economic development (Djeunankan et al., 2024), health (Hernández and Siegel, 2019), information attainability (Baffour Gyau et al., 2025), and access to water, sanitation, hygiene service (Mazenda, and Nkwana, 2025) and hinders prospects for the attainment of key SDGs.

Most communities in Nigeria are not isolated from global rural energy poverty, as the highest percentage of the population without access to electricity was located in rural areas (Best and Burke, 2018; Lewis et al., 2024; Johnson 2025). According to the World Bank report on Nigeria, the electricity access rate in the country stood at 55.4% in 2020 with a big gap between urban and rural areas (83.9% vs. 24.6%) (World Bank, 2021). At the same time, nearly 30 million Nigerian households depend on wood as a source of cooking fuel, the collection of which is time-consuming and mainly done by women (WHO, 2022). As a result, many rural dwellers are forced to rely on firewood for their energy needs, further exacerbating environmental challenges, such as deforestation, global warming, and climate change impacts. Statistics show that Nigeria lost 97.8-kilo hectares of natural forest in 2020, equating to 59.5 metric tonnes of CO_2 emissions (Ajayi, 2023). Tika and Hom (2020) also confirmed in their study that household CO_2 concentration was positively correlated with CO_2 emissions due to firewood burning, and daily CO2 emissions were 14.26 kg CO2 e/(household/day).

Burning of solid fuel in inefficient traditional stoves is responsible for the emission of various indoor air pollutants, which have direct and indirect impacts on the health of the inhabitants (Tika and Hom, 2020; Flammini, 2023). Exposure to pollutants resulting from the burning of solid fuels has been responsible for the death of at least 4.3 million people per annum worldwide (World Health Organization, 2016). This death is due to the inhalation of polluted air in households, stemming mainly from the traditional use of biomass for heating and cooking. Air is considered polluted when the mean concentration of particulate matter (PM_{10} and $PM_{2.5}$) and other combustion-derived indoor pollutants such as carbon monoxide are beyond the World Health Organization (WHO) air quality guideline values (WHO, 2014). Another study pointed out an estimation of 3 million deaths per year from indoor air pollution due to open fires and smoky stoves (International Energy Agency, 2021; WHO, 2021). In view of the above, coupled with the country's energy transition plan to reduce Nigeria's dependence on fossil fuels and promote renewable technologies towards Nigeria's net-zero commitment by 2060, there is a need for transition towards a more efficient and renewable energy sources, that will mitigate climate change impact as well as meet the energy demands of rural communities.

The deployment of renewable energy and energy efficient technologies for electricity generation, heat production for buildings and industry, and transport are key towards keeping the average global temperature rise below 1.5°C (Renewables, 2022). In 2022, renewable energy supply from solar, wind, hydro, geothermal, and ocean rose by close to 8%, meaning that the share of these technologies in the total global energy supply increased by close to 0.4 percentage points, reaching 5.5%. Modern bioenergy's share in 2022 increased by 0.2 percentage points, reaching 6.8% (Renewables, 2022).

Modern bioenergy is today the largest source of renewable energy globally, with a more than 50% share of global use in 2022 (Renewables (2023). International treaties, like Agenda 21 and Kyoto Protocol advocate for a transition to renewable and low-carbon sources of energy due to high greenhouse gas emissions associated with fossil fuels and the related climate change (Sahota et al., 2018; Moreau, and Vuille, 2018). Biogas has proved to have significant potential as a renewable energy source for industrial as well as domestic applications and an efficient solution to the global energy crisis (Kumar et al., 2018; Achinas *et al*., 2017).

The most common biogas technology in Nigeria is the digester system, such as Small-Scale Digesters (Fixed Dome Biogas Plants, Floating Drum Plants, Low-Cost Polyethylene Tube Digester, Balloon Plants, Horizontal Plants, Earth-pit Plants, Ferro-cement Plants) Industrial Digester Types (Batch plants, Continuous plants, Semi-batch basis (Itodo *et al*., 2021).

However, despite the gains from biogas technologies in Nigeria, deployment of the technology has been grossly inadequate. While some authors have attributed this limitation to the lack of framework for sustainability, Lack of regulation, absence of public ownership, and lack of financial incentives (Itodo *et al*., 2017), the fact that the biogas digester system is not attractive on large scale, as it is not economically viable (Ashenafi and Natei, 2022), limited potential for commercialized in the country due to its low energy content per unit volume, and difficult to liquefy (Temilola *et al*., 2014), studies on the aspect of social acceptance and the dimensions of social acceptability such as socio-political acceptance (state actor willingness), community acceptance (in terms of cultural/religious issues, income levels, technological know-how to sustain the technology), and market acceptance etc) are lacking. This gap in knowledge justifies the need for the present study.

2. MATERIALS AND METHODS

Study Area

The study area is Benin City, the administrative headquarters of Edo State. The latitude and longitude of Benin City is 6.3350° N, 5.6037° E. The total land area of all the three local government areas is 1,204km^2 (Isagba et al., 2019). According to Google Earth, the total land area of the continuous urbanized Benin City in 2016 is 531sq km. The city consists mainly of three local government areas Oredo, Egor and Ikpoba Okha Local Government Areas; it also consists partly of Ovia Northeast and Uhunmwonde Local Government Areas (See Figure 1). The land area of the three main local government areas is as follows: Oredo, 249km2; Egor, 93 km² and Ikpoba Okha, 862 km². According to the Nigeria Population Commission projected population figures for 2022, Benin City population at a growth rate of 3.31% is 1,841,000 (National Bureau of Statistics, 2023). For the purpose of this study however, our survey was limited to Oredo, Local Government Area.

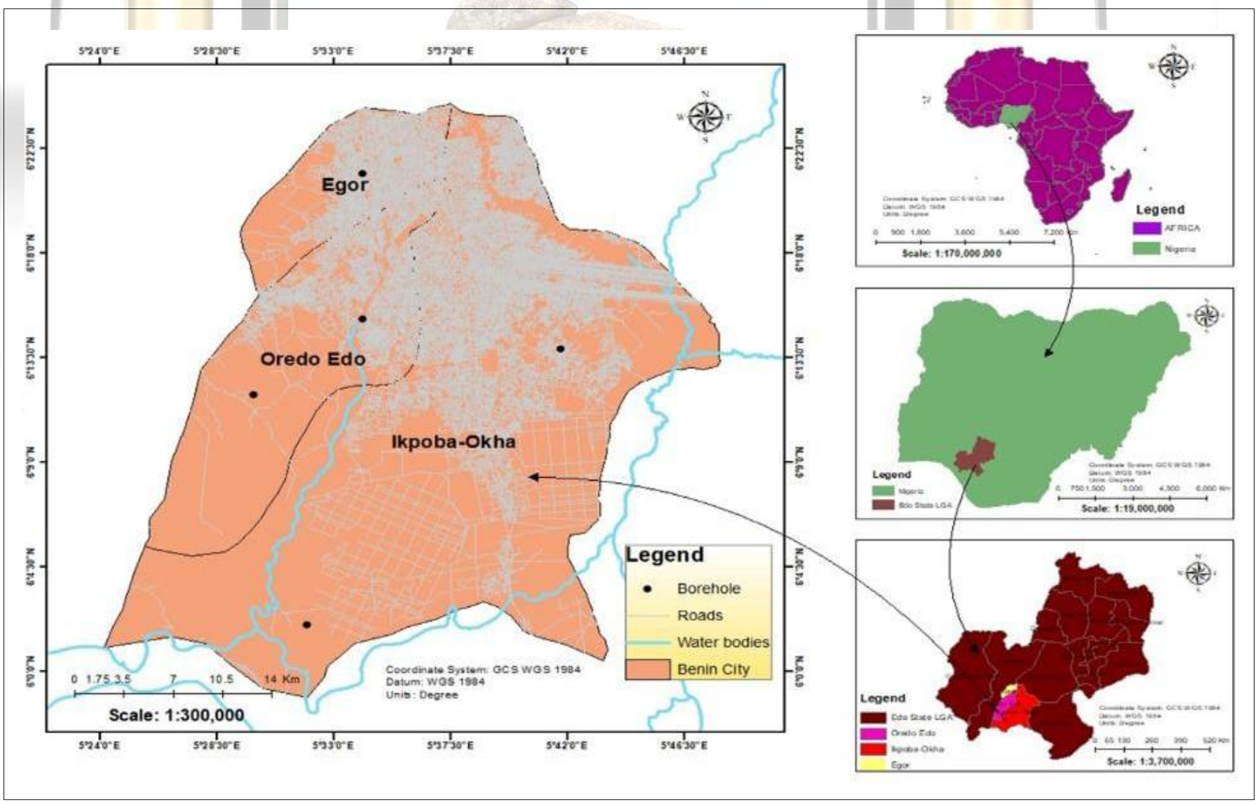

Figure 1: Map of the study area

Research Design

The study adopted an exploratory research design, which is suitable for investigating a phenomenon with little or no previous research. This design allows the researcher to gather preliminary data, identify problems, and develop hypotheses. The study also adopts a cross-sectional design, which will enable the researcher to collect data at a single point in time.

Population of the Study

The populations of the study are selected households, Ministries Department and Agencies of the State Government in Oredo Local government Area and Stakeholders in biogas technologies. The selection of Oredo LGA is influenced by the presence of the University of Benin, and the State Government House, factors which would affect respondent's level of awareness of biogas technologies. More so, communities in the sampled L.G.A were selected based on their willingness to be part of the survey.

Sample Size

The sample size was determined using the formula for calculating sample size for a finite population. The formula is:

$$n = (Z^2 \times P(1-P))/D^2$$

Where:

n = sample size Z = standard normal deviation at 95% confidence level (1.96) P = proportion of population estimated to have knowledge of biogas technologies (assumed to be 50%) D = margin of error (5%)

Using the formula, the sample size will be:

$$n = (1.96^2 \times 0.5 \times 0.5) / (0.05^2) \quad n = 384$$

Though the calculated sample size is 384 households, for the purpose of increasing the representativeness of the population, the sample size was increased to 420.

Data Collection

Both field work, primary and secondary data were used for the study. Primary data was obtained through the administration of structured questionnaires and utilization of oral interviews where necessary. The questionnaire was divided into three sections, Parts A, B, and C. Part A included questions related to socio-demographic information such as household's gender, age, educational level, types of energy applications (lighting/non-lighting & cooking/non-cooking activities), current sources of electricity/energy, reason for the choice of energy source (s) costs of energy usage, satisfaction with current energy sources etc. Part B is a question related to their knowledge of biogas technologies, their level of knowledge of energy production from waste including organic waste and cattle rumen, sources of knowledge of waste-to-energy technologies, willingness to adopt W-T-E technologies, willingness to pay/be trained on W-T-E technologies, while Part C is a question about their acceptability indices of biogas technologies

(W-T-E). These indices induce W-T-E technologies and cultural/religious issues, W-T-E technologies and income level, W-T-E technologies and technological know-how to sustain the technology, W-T-E technologies and socio-political acceptance, W-T-E technologies and market acceptance. Respondents were asked to select the correct and appropriate answers for the questions on knowledge and awareness of environmental impacts of pesticides usage.

Sampling procedure

The study adopted both systematic random and purposive sampling methods in the selection of respondents. McMillan and Schumacher (1997) describe purposive sampling as "selecting information-rich cases for study in-depth" when one wants to understand something about those cases without needing or desiring to generalize to all cases. In this case, experts (private and state actors) in biogas technologies within Oredo L.G.A. The study area was first arranged into twelve (12) wards/quarters that make up the L.G.A. In each ward, the number of streets was counted and on the basis of this total, every third, fourth or Fifth Street was selected for the administration of the questionnaire. Secondly in each selected street, systematic sampling method was again employed in the selection of houses for the questionnaire administration. This involved selecting every fifth house on both sides of the selected street for questionnaire administration. Finally, the questionnaire was administered to only one household in each selected house. On the whole a total of Thirty-five (35) respondents were sampled from each ward/quarter (Table 1).

Table 1: Wards/Quarters Surveyed in Oredo L.G.A, Benin City

	Community/Quarter	Number of questionnaires distributed	No, questionnaire retrieved responses %
1	Ogbe	35	100%
2	GRA/Etete/Iyekogba	35	100%
3	Uzebu	35	100%
4	Urubi	35	100%
5	Oliha/Ukhegie	35	100%
6	Iyaro/New Benin I	35	100%
7	New Benin II,	35	100%
8	Oredo	35	100%
9	Ikpema/Eguadase	35	100%
10	Unueru/Ugboka	35	100%
11	Ogbelaka/Nekpenekpen	35	100%
12	Ibiwe	35	100%

Reliability and Validity of Research Instrument:

The reliability of the research instrument was assessed using test-retest reliability. This involved administering the questionnaire to a sample of smallholder farmers twice with a time interval of two weeks. The results were analyzed using the test-retest correlation coefficient to determine the reliability of the questionnaire. The validity of the research instrument was assessed using content validity. This involved assessing the relevance and comprehensiveness of the questionnaire by experts in the field of biogas technology.

Data Analysis

Statistical Analysis: The data were prearranged and entered in the MS-Excel spreadsheet and then analyzed using Statistical Package for the Social Sciences (SPSS) version 20. Chi-square test was applied to test for probable associations between variables. The results were presented in frequencies, and percentages for specific variables, and as mean ± SD for continuous variables. The significance levels were set at $P \leq 0.05$.

Five-point response analysis

Respondents were asked to select the correct and appropriate answers for the questions on level of awareness of biogas production from organic waste materials, including fecal material and their social/cultural acceptance. A total of five (5) points were given to very much aware (5), moderate awareness (4), Undecided (3), low awareness (2), and never aware (1). Adding all the ratings together gave us a total of 15 points. In our interpretation, any mean above 4.5 is very high, 3.5 and above high, 3.4 -2.5 moderate or uncertain below 2.5 is poor or low.

3. RESULTS AND DISCUSSION

Respondent Socio-demographic Profiles

The results for the respondents' socio-demographic survey (Table 2) revealed that the majority of sampled respondents were male with 258 study participants (61.42%), while 162 (38.57%) were female (38.0%). This disparity in sex composition of respondents confirms previous studies on female –male gender ratio (Olonadea et al. 2021; O'Neill, 2023; USAID 2023). For example, O'Neill (2014) reported that in 2023, Nigeria's female population amounted to approximately 110.67 million, while the male population amounted to approximately 113.13 million inhabitants. This disparity has also been reported in women's participation in the national economy as about 11 percent of women are presented in the national economy compared with 30 percent for men (Olonadea et al. 2021).

In Table 2, the majority of the respondents were within the age bracket of 31 years - 40 years (30.23%), followed by respondents within the age bracket of 41 years to 50 years (24.28%). The age brackets are considered important for this study as having full knowledge of the subject matter under investigation, especially as most of the respondents by this age are expected to have completed higher education programmes and acquainted with IoT where information on biogas technologies can easily be accessed. The above finding is also in line with the workforce trend for public service in Nigeria and shows the reliability of our research instrument. For example, as of 2020, of the 80 million total workforce in Nigeria, the population within the age 25 to 34 years old represented the largest labor force population in the country, with around 23 million people. Individuals from 35 to 44 years old made up the second most numerous groups, with over 20 million people (Sasu, 2022). Across the world, studies have shown that adolescents and young adults use the Internet more frequently than older generations (older adults) and in a more multipurpose context (Tzavela et al., 2015, Casaló and Escario, 2018).

The 2022 Pew Research Center survey found that 86% of those ages 30–64 owned broadband access at home compared to 61% of those ages 65 and older (Faverio, 2022). Similarly, using European data, König, Seifert, and Doh (2018) showed that less than 10% of those aged 80 and older accessed the Internet, whereas 48% of Europeans aged 65–69 did. In another study Benvenuti et al., (2023) showed that around 71% of young people worldwide are internet-users compared to 48% of the world's population (older population). The highest reported percentage of internet users in this age group is in Europe where 97% of 15- to 24-year-olds are internet users. Similarly, in many developing countries, the use of technology among adolescents and young adults is increasing rapidly, with smartphones, mobile apps, and social media platforms featuring prominently in the daily lives of many adolescents (Benvenuti, 2023). Overall Quan-Haase et al., (2018) reported that the older population is at lower odds of integrating internet use into everyday activities and uses the internet in more limited ways owing to lower literacy, inability to see the benefits of online engagement, and, sometimes, genuine disinterests in using the internet. Studies have attributed this to the fact that older adults are overwhelmed by the variety of ICT functions and struggling with a lack of clear instructions and adequate support, which resulted in an inability to expand usage and increasing frustration with learning new things (Vaportzis et al., 2017; Harris et al., 2022). Generally, respondents are married (62.14%), while 30.47%. falls under the unmarried (single and divorced) group. Divorced population both males and females constituted 31 (7.38%) of the sampled population.

The educational level of sampled population (Table 2) showed that the majority of respondent's university/polytechnic graduates (25%) and this might explain the high use of IoT amongst respondents. Education is directly linked to technological use and applications. Education systems around the world integrate technology into teaching-learning-assessment processes (Ibanez et al., 2016; Silverajah and Govindaraj 2018) and develop students' digital skills (Porat, et al., 2018), hence the higher the level of education the greater the ability to use biogas technology. The high number of respondents with university/polytechnic degrees is also expected in view of the spread of several institutions of higher learning, including the University of Benin, Benson Idahosa University, Auchi polytechnic, Wellspring University, Igbinedion University Okada etc (Table 2). With respect to the income levels of respondents' majority (31.19%) reported an average monthly income of ₦50,000-100,000, followed by another group (₦100,000-150,000) (Table 2). The low-income level across the study area was generally linked to the lack of white-collar jobs and the fact that insecurity and kidnapping has limited farming activities in the northern part of the state where most of the respondents owe farmlands. Majority of respondents are either employed by the State Government into various Ministries, Department and Agencies or federal government of Nigeria such as University of Benin, University of Benin Teaching Hospital, Federal Unity Schools (Table 2). On the general level of knowledge of biogas technologies in the study area the majority (54.04%) reported they are aware of the technologies (Table 2).

Table 2: Socio-demographic characteristics of the respondents

Variables	Frequency (n = 420)	Percentage
Gender		
Male	258	61.42
Female	152	38.57
Age group		
30 years and below	68	16.19
31 – 40 years	127	30.23
41 – 50 years	102	24.28
51 – 60 years	64	15.24
61 – 70 years	40	9.52
70 years and above	19	4.52
Marital status		
Married	261	62.14
Not married	128	30.47
Divorced	31	7.38
Highest educational qualification		
No formal Education	78	18.57
School Certificate	83	19.76
Secondary school	95	22.6
B.Sc./HND	105	25
Postgraduate qualifications	59	14.04
Mean income level per month		
Less than N50,000	23	5.47
N50,001 – N100,000	131	31.19
N100,001 – N150,000	129	30.7
N150,001 – N200,000	81	19.28
N200,001 – N250,000	42	10
N250,000 >	14	3.33
Occupation of Respondents		
Personal Business/buying & selling	132	31.42
Public servant	141	33.57
Combined (public service/business)	92	21.9
Farming	55	13.09
Knowledge of Biogas technology		
Yes	227	54.04
No	193	45.95

In Figure 2, it can be seen that the predominant source of biogas technology information available to respondents is social media (Facebook, twitter, Instagram, LinkedIn, TikTok, YouTube) (62.38%). This was followed by seminars/conferences organized by Ministries, agencies of the government and private sectors on biogas development. Study has found that social media enabled online sharing to become a daily activity, (Tseng et al., 2017) and large-scale use promotes information dissemination, which may produce information dissemination effects (Yang et al., 2023). According to Tetteh et al., (2024), social media is widely used by young people in Africa, and studies have found that high school and university students in countries like Ghana, Nigeria, South Africa, and Kenya use social media the most frequently, with other research revealing trends in both their urban and rural areas (Sibanda, 2020; Umar & Mohammed, 2022). Even though social media is widely used, there are differences in usage between younger and older youth, males and females, and urban and rural locations. Age and gender so have an impact on how social media programs are used and preferred (Amoah, Citation 2021a, 2021b)

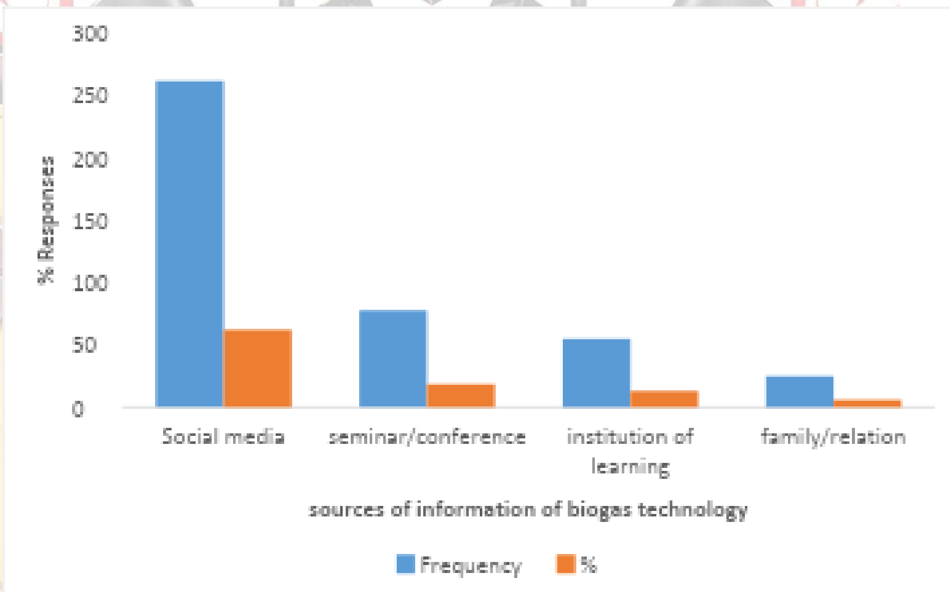

Figure 2: Sources of information on Biogas technologies

In Table 3, existing sources of fuel are presented. LPG (36.19%) was reported as mostly used, followed by fuel wood/biomass (charcoal). Similar pattern was reported by Nshimiyimana et al., (2024) in Rwanda where LPG is regarded as one of the fastest solutions to curb biomass demand in Rwanda, although its presence is mostly limited to urban areas and high-income households.In other study, Clean Technology Hub (2023) reported that Liquefied Petroleum Gas (LPG) is the most commonly used cooking fuel in the South-South and South West geopolitical zones and in major cities where incomes are higher and LPG distribution networks are accessible. Within the context of Nigeria Energy Transition, clean cooking value chains (LPG, improved biomass cookstoves (ICS), and other renewable fuels) are emerging nationwide (Roche et al., 2024).

Study has found that with a current penetration of over 35 % in urban households (National Bureau of Statistics 2020) (up from just 7 % a decade ago), the LPG value chain is quickly becoming firmly rooted in the Nigerian market (Table 3). More so, the policy and enabling environment for LPG has recently improved, and a drive to attract large-scale private sector investments (BusinessDay, 2015). Next to LPG is fuel wood (25.95%). In a similar study, Roche et al., (2024) reported that solid biomass is the primary fuel in two-thirds of Nigerian households, mainly in rural areas. The study further revealed that the primary cookstove in most households (51 %) is a 3-stone open biomass fire, whereas 9 % use self-built biomass stoves and 5 % use manufactured biomass stoves. Households predominantly use fuelwood, but charcoal makes up 4–6 % of the biomass used. The use of biomass fuel is particularly prevalent in rural Nigeria, where it is used by over 85 % of households - much of it outside of the commercial fuel market (UNICEF, 2018; National Bureau of Statistics 2019). Kerosene also remains an important cooking fuel (17 % of Nigerian households in 2019) despite a rapid decrease in recent years due in part to the removal of a longstanding government subsidy (UNICEF, 2018; National Bureau of Statistics 2019). On the drivers of fuel choice, most of the respondents reported that low cost of fuel sources is a major (38.33%) while others report availability of fuel sources (31.9%). Similar observation was reported by a change in the prices of close substitutes that will also have an effect on the individual cooking energy sources. Some studies in Nigeria have also evaluated the effects of Income, fuel accessibility, type of dwelling, household size, level of education (especially of the head of the household), as significant determinants of household cooking fuel choice in Nigeria (Emodi et al., 2022; Oyeniran and Isola, 2023; Ozughalu, 2023). For example, Emodi et al. (2022) find that fuel price elasticity is stronger in rural households, suggesting that changes in fuel prices are more likely to make them move up or down the 'energy ladder (i.e., towards cleaner fuels or away from them) than in the case of urban households. Their study found a significant number of Nigerian households 'backsliding' towards lower-quality fuels between 2010 and 2018. Jewitt et al. (2020) used qualitative data to show the widespread use of fuel 'stacking' (use of multiple fuels) to shield against variations in fuel prices, access, and reliability of supply.

In Table 4 and Figures 3-6, perceived economic cost of existing fuel sources and levels of satisfaction of fuel sources are presented. There are mixed responses on the perceived economic burden of available fuel sources with some respondents reporting a high economic burden while others claiming that their present fuel source is relatively cheap. There are also mixed responses regarding the level of satisfaction with some respondents with their existing fuel sources while others expressed dissatisfaction due to the rising cost of fuel sources. These mixed responses may be linked to the effects of price and availability of fuel sources.

Table 3: Existing sources of fuel

Variables	Frequency (n = 420)	Percentage
Source of fuels		
Kerosene	102	24.28
LPG	152	36.19
Electricity (Grid)	57	13.57
Fuel wood/Biomass (Charcoal)	109	25.95
Others (specify)	102	24.28
Reason for choice of fuel sources		
Easily Available	134	31.9
Cheap	161	38.33
Easy to use	56	13.3
Familiar fuel	22	5.24
No other fuel available	47	11.19

Table 4: Perceived economic cost of existing fuel sources

Variables	Frequency (n = 420)	Percentage
Kerosene		
Very costly	167	39.76
Not sure	77	18.33
Moderate	101	24.04
Relatively cheap	75	17.85
LPG		
Very costly	211	50.23
Not sure	82	19.52
Moderate	92	21.9
Relatively cheap	35	8.33
Electricity (Grid)		
Very costly	261	62.14
Not sure	51	12.14
Moderate	87	20.7
Relatively cheap	21	5.0
Fuel wood/biomass		
Very costly	19	4.5
Not sure	22	5.23
Moderate	106	25.2
Relatively cheap	273	65

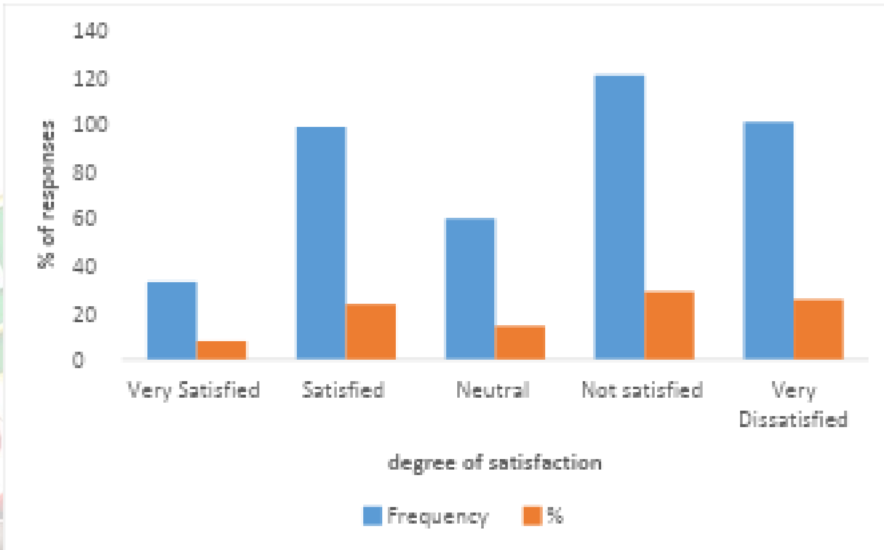

Figure 3: perceived Satisfaction with Kerosene use as fuel

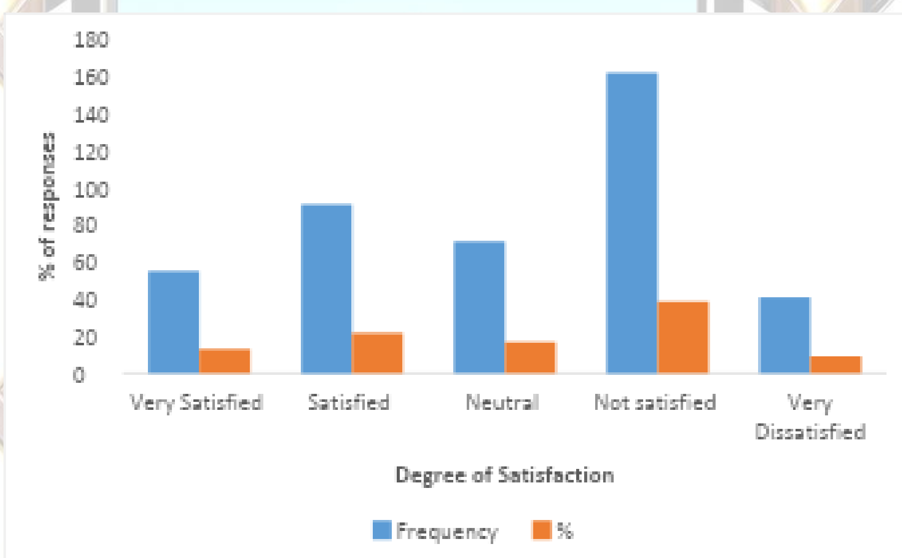

Figure 4: perceived satisfaction with LPG use as fuel

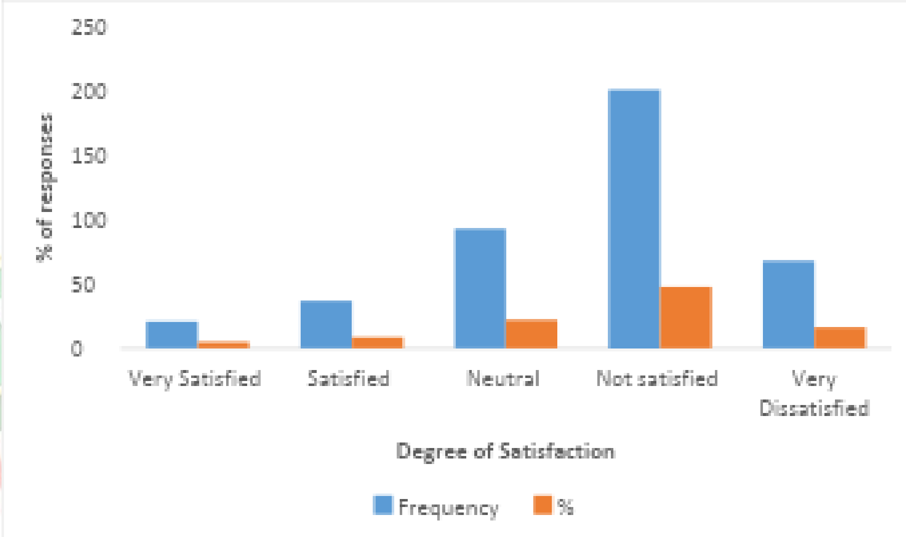

Figure 5: perceived satisfaction with electricity (grid) use as fuel

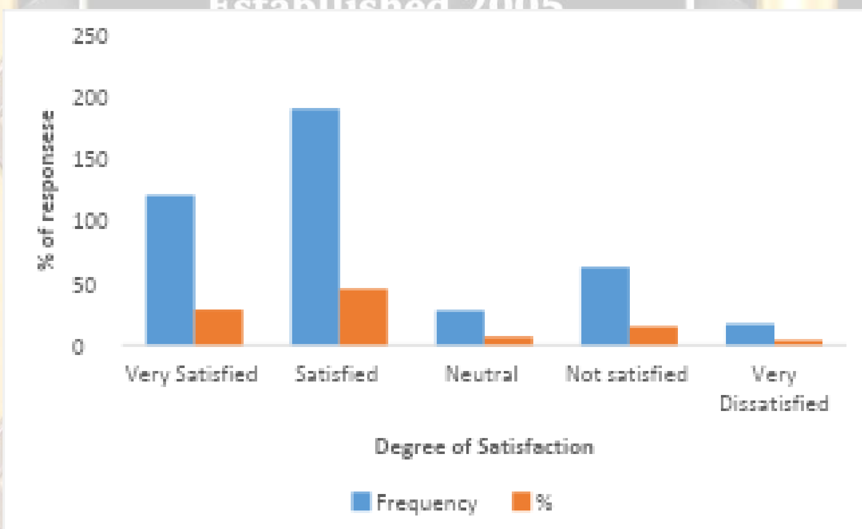

Figure 6: perceived satisfaction with Fuel wood /Biomass (Charcoal) use as fuel

In Table 5 awareness levels of biogas technologies are presented. On the whole there is low to moderate level of awareness of waste-to-energy technologies and biogas feedstock and has implications for biogas technology deployment. According to Uhunamure et al., (2021), awareness of any technology in terms of the functions and services it can provide is a vital factor to the user. Bharadwaj et al., (2023) reported similar observations in Australia and attributed this to lower social acceptance. In Limpopo Province and many other provinces in South Africa, Eghosa et al., (2020) also reported limited growth in the dissemination of biogas technology due to awareness and perceptions of the technology. ALFA Consortium, (2023) in their study perceptions, acceptance levels and needs on biogas reported lack of awareness and understanding of biogas among the general public in the European Union. In their study on the economic analysis of biogas adoption technology by rural farmers in Pakistan Abbas, et al., (2017) revealed that the adoption of the technology is hindered by effective strategies such as awareness through public service advertising, e.g., print and electronic media, and by the different models of biogas plants that best suit the condition of the rural households. For the most developing countries, Patinvoh, and Taherzadeh (2019) reported that the associated challenges with policy, technical services, funding, awareness, education and sustainability were among the factors hindering the implementation of biogas in developing countries. Other factors have also been investigated such as technical issues, operational issues, policy issues etc as stumbling blocks in the advancement of biogas technology. For example, In Ethiopia, a feasibility report on domestic biogas adoption outlined the limiting barriers and challenges to include technical issues, operational issues, economic issues, dissemination issues and policy issues as the stumbling block in the advancement of the technology (Eshete et al., 2006). Similarly in Pakistan, the willingness of rural communities to adopt a biogas system was hindered by the demographic and socio-economic status of the households as reported by Inayatullah, and Waqar (2016). Their study indicated that age, educational level of the household head, household income, total landholding of the household and number of livestock owned was among the influencing factors Inayatullah, and Waqar (2016). In India Mottaleb, and Rahut (2019) reported that both physical capital, such as house ownership and landholding, and human capital, such as education, are barriers to the technology adoption.

Table 5: Absolute and Relative Frequency Distribution of level of awareness of biogas technology and feedstock

Knowledge of Levels of biogas technologies/feedstock	5 High	4 Moderate level of awareness	3 Undecided	2 Low level	1 Zero Awareness	Mean	Standard Deviation	Knowledge level
Knowledge of biogas technologies (types, financial implications, feedstock, technicalities and functionality etc)	46 (10.9%)	96 (22.9%)	84 (20%)	102 (24.3%)	92 (21.9%)	2.8	0.25	Moderate
Knowledge of biogas production from residential organic waste	31 (7.38%)	52 (12.4%)	18 (4.3%)	190 (45.2%)	129 (30.7%)	2.6	0.31	Moderate
Knowledge of Use cattle rumen/poultry droppings/fecal material for biogas production	24 (6.7%)	41 (9.76%)	66 (15.7%)	78 (18.6%)	211 (50.2%)	2.0	0.08	Low
Knowledge of economic benefits of biogas technologies (investment opportunities, job creation and improved livelihood	114 (27.1%)	107 (25.5%)	72 (17.1%)	84 (20%)	43 (10.2%)	3.4	0.51	Moderate
Knowledge of benefits of biogas deployment to mitigate climate change	102 (24.8%)	121 (28.8%)	56 (13.3%)	79 (18.8%)	62 (14.8%)	4.3	0.43	High
Knowledge of bio fertilizer from biogas facility	18 (4.2%)	31 (7.4%)	44 (10.5%)	167 (39.7%)	160 (38.1%)	1.98	0.23	Low
Perception of market readiness for biogas technologies/feedstock	118 (28.1%)	107 (25.5%)	31 (7.4%)	98 (23.3%)	66 (15.7%)	3.26	0.54	Moderate
Perception of social, cultural and technical issues with waste-to-energy (Biogas) deployment	94 (22.4%)	129 (30.7%)	28 (6.7%)	101 (24.0%)	68 (16.2%)	3.13	0.51	Moderate
Knowledge of Energy Transition Plan to phase out fuel wood in 2030	12 (2.9%)	44 (10.5%)	110 (26.2%)	172 (40.5%)	82 (19.5%)	2.35	0.32	Low

Above 4.5 is very high; 3.5 and above high; 3.4 -2.5 moderate; below 2.5 is low level of awareness

In Table 6, perceived social acceptance factors with potential to affect deployment of biogas technologies are presented. Economic concerns such as household income levels/investment opportunities (39.8%) ranked highest, followed by the perceived complexity of the technology (35.6%) in terms of ease of construction and operation will have a very strong effect on deployment. On the other hand, socio-political/government willingness to promote biogas policies (32.8%), cultural issues associated with handling feedstock such as cattle rumen/poultry dropping (33.1%) were perceived as having strong effects on the deployment of biogas technologies. The above findings are consistent with previous studies (Mengistu et al., 2016;

Taherdoost 2018; Uhunamure et al., 2021). For example, in Ethiopia Mengistu et al., (2016) reported that income level, access to credit were identified as key factors influencing households' decisions in biogas technology adoption. Uhunamure et al., (2021) in their study in selected South Africa provinces reported that access to loans, credit and subsidies are key determinants of a household's intention to adopt biogas technology. Rogers (2003) has also identified five attributes that can accelerate or impede the adoption rate of the technology. These attributes are relative advantages, trialability, observability, complexity and compatibility. According to Eghosa et al., (2020) modern biogas technology is evaluated in economic terms according to its social status, satisfaction and convenience. A technology that can easily be experimented with its appropriateness with observable results is expected to be more rapidly adopted than others. In the traditional adoption technology model, Taherdoost (2018) argued that primarily a consumer's adoption is determined by the 'perceived ease of use' and the 'perceived usefulness/benefits' of the technology and this is evident from this present study.

Cultural influence is defined as the behavioural patterns, values, beliefs and norms of a group of people in society for specific professions, and local or national culture (Leung et al., 2005). According to Uhunamure et al., (2021) argued that cultural norms have a fundamental correlation with biogas adoption. Some traditions and religions have strict rules regarding cleanliness, which to a larger extent are not connected to animal excrement alone but also human excreta (GTZ, 1999). Dahlin et al. (2015) demonstrated that products derived from digestate containing pig slurry cannot be marketed to Islamic countries. Stigmatisation issues are central to biogas operations and export to other countries. Arthur et al., (2011) reported that stigmatizing the utilization of human excreta or even cow dung as substrate to biogas digesters, has the potential of discouraging its dissemination. In Zambia, women could not collect cow dung as it was against their traditions (Shane et al., 2015). In Kenya, some households expressed doubts over the "cleanliness" of biogas coming from some types of waste (Sovacoo et al., 2015). According to Khan et al., (2014), concern of personal hygiene and stigmatization could lead to problems regarding the management of feedstock and slurry, as many users are not willing to do the daily dung mixing required, considering it a dirty job. Objections to using animal and human excrement as raw material in some cultures has been reported as impediment to technology adoption (Shen, et al., 2015; Rupf et al., 2015; Situmeang et al., 2022). Ghosh and Mandal (2018) reported that most biogas projects across the world failed because they were incompatible with local beliefs.

The effects of political will and institutional capacity were also acknowledged by respondents to have strong effects on the deployment of biogas technologies, and this is in consistent with previous studies such as (Giwa et al., 2017; Osunmuyiwa and Kalfagianni 2017; Nevzorova and Kutcherov, 2019; Nwankwo et al., 2024). Osunmuyiwa and Kalfagianni (2017) for example considered the role of the regime and particularly political actors in enabling the adoption of biogas technology in Nigeria, which will be relevant to improving the welfare of Nigerians. Several studies have acknowledged the importance of tax waiver, incentives, and governmental support for biogas generally (Muradin and Foltynowicz, 2014; Martin, 2015; Msibi and Kornelius, 2017; Ammenberg, and Feiz, 2017).

Table 6: Perceived effects of social acceptance indices on waste-to-energy deployment

Variables	Frequency (n = 420)	Percentage
Economic concerns (Household income levels/investment opportunities)		
Very Strong effect	167	39.76
Strong effect	101	24.04
Neutral (not sure)	14	3.33
Moderate effect	97	23.09
Zero effect	41	9.76
Complicity Technological		
Very Strong effect	141	35.57
Strong effect	116	27.62
Neutral (not sure)	09	2.14
Moderate effect	107	25.5
Zero effect	47	11.19
Socio-Political acceptance/Government willingness		
Very Strong effect	153	36.4
Strong effect	171	40.7
Neutral (not sure)	-	-
Moderate effect	52	12.38
Zero effect	44	10.48
Market readiness		
Very Strong effect	91	21.7
Strong effect	138	32.85
Neutral (not sure)	67	13.95
Moderate effect	102	24.3
Zero effect	22	5.23
Cultural issues with feedstock handling (cattle rumen, poultry droppings)		
Very Strong effect	101	24.04
Strong effect	139	33.09
Neutral (not sure)	65	15.47
Moderate effect	88	20.95
Zero effect	27	6.42

4. CONCLUSION

The full deployment of biogas technologies has a high potential to mitigate climate change as well has put the country on the path of achieving its Energy Transition Plan objectives. However, several barriers still exist that hinder commercialization of biogas technologies, ranging from technical concerns, economic prospects, market readiness, institutional framework, environmental and soci0-cultural. The present study focuses on the level of awareness of biogas technologies and socio-cultural acceptance issues relating to the adoption of biogas technology in Benin City. Dimensions of social acceptance examined in the study include household income levels/investment opportunities, perception of the complexity of the technology, perceived institutional framework, perceived market readiness and cultural issues that border on religious belief, personal hygiene and stigmatization associated with feedstock handling such as cattle rumen, human excrement and digestate containing pig slurry.

There is generally low to moderate level of awareness on biogas technologies in Benin City and presently only few organizations of government such as the National Centre for energy and Environment, Energy commission of Nigeria and few private sectors such as Presco Plc in Obaretin There is at the moment zero deployment at household levels. The low to moderate levels of awareness of technology is attributed to poor knowledge of the technology types, functionality, techno-economic viability, environmental implications and poor orientation of feedstock handling.

On economic concern such as household income level and investment opportunities as they related to household and commercial adoption of biogas, there is a very strong perception that initial cost of construction can serve as barrier to household use of the technology, while the prospect for investment opportunities in the technology may be low to the lack of clear institutional framework to provides strategic biomass technology development, deployment and utilization in the country.

There was also a very strong perception and apprehension on complexity of constructing and operational maintenance of the technology at household level. This perception emanates from the fact that biogas technology and operations require technical training which may put extra financial burden on households, especially the low- and average-income earners.

Results indicated there are very strong cultural and religious concerns regarding handling of feedstock from organic waste, animal and human wastes. These cultural and religious concerns are expressed in the form of stigmatization, hygiene apprehension, management of feedstock and slurry, as many users may not be willing to do the daily dung mixing required, considering its dirty nature. There is also the belief that some religions forbid handling digestate containing pig slurry. Strong government will and institutional capacity was also perceived as a strong factor of biogas deployment. Institutional framework to encourage investment through providing economic incentives, political support to investors/private sector participation, providing legislation framework for biogas deployment/deployment as well as championing advocacy on awareness and sensitization on the technology.

5. RECOMMENDATIONS

In view of the study findings, the following are recommended the need for the government to create special financial support programmes to provide soft loans to boost the attractiveness of biogas projects to the investors and households. This is especially due to the high investment costs associated with biogas technology, which is compounded by widespread poverty in many communities in Nigeria. A key feature of biogas technologies is that almost all expenses are upfront, while operating expenses are very low. This fact creates problems for potential users with a low capital base.

Secondly, there is a need for government and private sectors to establish training and innovation hubs in renewable energy technologies (biogas technologies) using local contents. Such training and re-training should focus on the operation and maintenance of biogas technology. Such training should also target technicality, functionality and management of biogas digestate.

Thirdly, in order to address the socio-cultural limitations bordering on religion and personal hygiene, there is a need for comprehensive and intensive educational campaigns, beginning from institutions of learning to communities to promote the benefits and awareness about technology.

Across developing countries, a lack of private sector participation and poor coordination between the public and the private sectors has been identified as challenging factors to biogas uptake. There is therefore a need to develop a framework to increase private sector participation. This is essential as the private sector plays a key role in promoting biogas energy to the market and making it commercially stable.

Finally, innovations in the renewable energy industry usually require a network of actors where effective collaboration is an essential component in collaborative projects. Success stories from internationally can help developing countries create new technologies. Such Institutional networking can also serve to reduce the cost of biogas technologies and make it affordable for poorer households to invest in it, as well as to create more training-, consultation- and educational programs for biogas adopters.

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